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Vol 246 No 3285
Cover image: Victor Moatti

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A new era of space travel and bending the climate change curve. Plus: odd bumblebee behaviour and a close brush with another galaxy.

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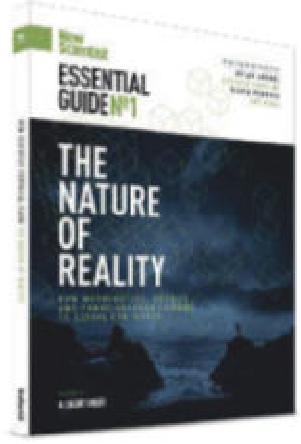

Essential guide

The first in a brand new series, our *Essential Guide: The Nature of Reality* explores how physics, mathematics and consciousness combine to make the world around us using classic material from the *New Scientist* archive. Read an extract on page 46 in which philosopher Nick Bostrom asks: is reality just a computer simulation?

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The compact television studio that lets you create training videos and live streams!

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CORONAVIRUS CRISIS APPEAL

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LILI-MARIE WANGARI IS MSF'S EMERGENCY COORDINATOR IN KENYA

An MSF infection prevention and control supervisor measures disinfectant to be used in cleaning an isolation area for COVID-19 patients in Likoni, Kenya. Photograph © Yann Libessart/MSF

Médecins Sans Frontières/Doctors Without Borders (MSF) is providing urgent medical care and support in more than 70 countries to counter the COVID-19 pandemic. In Nairobi, the Kenyan capital, MSF teams are working in Kibera, one of the largest slum settlements in Africa.

"Because we know Kibera, we know how catastrophic an outbreak could be in this community.

We've worked here for more than 25 years, through the HIV/AIDS crisis in the 1980s, when we cared for people at home, campaigned for access to treatment and were the first doctors to provide antiretroviral drugs to patients in a Kenyan public health facility.

Maintaining physical distance in Kibera is almost impossible, as it is in many slum settlements around the world. People live in tiny, overcrowded homes with few windows or other ventilation. These conditions make it easy for a disease like COVID-19 to spread, and very difficult for people to stay inside for long periods.

Access to clean water is extremely limited, with only 200 water points for the 200,000 people who live in the settlement, making regular hand-washing almost impossible.

My greatest concern is that a large proportion of people here have underlying health conditions, such as HIV and TB, and diseases, like hypertension and diabetes, that could put them at increased risk of developing severe COVID-19.

WHAT IS MSF DOING?

For the past two weeks, a team of MSF staff have been setting up a screening system in a tent at the entrance of a health centre in Kibera. We take patients' temperatures and control the number of people who come into the health centre at any one time. Should people have a fever, they go to see an MSF nurse for a more in-depth health check. We also have a clinical officer who manages an isolation room for suspected COVID-19 cases.

Our team is also providing training and support for infection prevention and control measures. This includes making sure staff are wearing the correct personal protective equipment, such as masks and gloves, and that there is a constant supply of water for hand-washing.

As well as making sure patients are safe, we want to protect health workers. Without them, there will be no response to COVID-19 and we could see a rise in deaths from unrelated health conditions. In the middle of this pandemic, we are determined that healthcare in Kibera will continue."

We are using nearly 50 years of experience fighting epidemics to protect the most vulnerable and save lives.

WE'RE SENDING MEDICAL TEAMS
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Highs and lows

We must learn from ingenuity of space travel to solve problems close to home

"CONGRATULATIONS to America – this has been an amazing two days," NASA administrator Jim Bridenstine said on 31 May, as two astronauts arrived on the International Space Station. They had launched the day before, carried into orbit by a SpaceX Crew Dragon capsule.

The launch was a major milestone for US space flight (see page 12), but many people in the US weren't in the mood for either congratulations or celebrations. The evening after Bridenstine's remarks, nationwide protests against police brutality and racism continued in the wake of the homicide of George Floyd, who died after a police officer pinned him to the ground by his neck.

As the US coronavirus death toll exceeded 100,000 people, hospitals had to treat both those with covid-19 and protesters hit with pepper spray and rubber bullets. US president Donald Trump was reportedly moved to a White House bunker normally reserved for terrorist attacks.

The dichotomy evokes the 1970 poem *Whitey on the Moon* by Gil Scott-Heron, about the neglect and oppression suffered by African Americans while the US government spent its money sending white Americans into space. At that time, many people in the US felt similarly about the Apollo programme – why go to the moon with so many problems to solve right here on Earth?

> "Hospitals had to treat both those with covid-19 and protesters hit with pepper spray and rubber bullets"

The question remains a good one. On top of our long-term problems, such as climate change, inequality and systemic racism, we are in the midst of a pandemic in which 6.3 million people have been infected with a coronavirus that we cannot yet treat or vaccinate against – and that figure is likely to be a significant underestimate.

Now, as then, though, it is important we keep looking to the stars. The SpaceX launch, watched by millions, was a big achievement. The astronauts, floating around in microgravity, are doing science that will surely pave our way to the moon and beyond. We cannot know where our forays into space will ultimately take us, but such endeavours show what humanity can do when we pull together to achieve something big – an approach we must emulate if we want to fix the more worldly problems we face. ▮

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GUY BELL/SHUTTERSTOCK

A school in London was one of many open to some children on 1 June

Too much, too fast?

The UK government has been criticised for lifting some coronavirus lockdown restrictions too quickly, reports **Adam Vaughan**

LOCKDOWN in England was further relaxed on 1 June, with groups of up to six people allowed to meet in a socially distanced manner outside, and schools encouraged to open to some year groups. But the UK Association of Directors of Public Health (ADPH) said in a statement that it feared the government was "lifting too many restrictions, too quickly".

The group said there were signs over the weekend that the public was no longer so strictly following guidance. A relatively high R – the average number of other people one case is likely to infect – of between 0.7 and 0.9 for the UK means "the room for manoeuvre is tight", the ADPH said. It is essential to keep R below 1 to keep the outbreak in decline.

"It's a little bit of wiggle room, so we will not be able to go all the way back to normal," says Neil Ferguson at Imperial College London. "Contact tracing will help. That gives us a bit more leeway, but it's not a panacea. It's not sufficient to allow everybody to go back to normal."

Ferguson and his colleagues have analysed anonymised mobile phone data and say the public's adherence to social distancing and restrictions has been high across the UK, although concerns remain over whether potential breaches of guidance by prime minister Boris Johnson's chief adviser, Dominic Cummings, have damaged public trust and could hurt future rule compliance.

As part of the efforts to lift lockdown, about 25,000 people have been recruited to work on a test and trace scheme in England. They will phone those who test positive for the disease to establish their recent close contacts and then call those people to tell them to self-isolate. Similar programmes have launched in Wales, Scotland and Northern Ireland.

However, an accompanying app, which could notify people that they may have been exposed to the virus by nearby strangers, is now more than a fortnight late. There is no public date for when it will launch nationally, although it has been piloted on the Isle of Wight. The Department of Health and Social Care didn't respond when asked to confirm a date.

In the meantime, the test and trace programme will be able to handle 10,000 new covid-19 cases per day and soon there will be 200,000 tests daily, the government has said.

Testing figures show that there were more than 2000 new cases a day across the UK in the last week of May, but two separate analyses, by the Office for National Statistics (ONS) and researchers at King's College London, say the reality is probably about 8000 a day, because most people with the disease won't be tested.

Given that the contact tracing system is new and the tracers are part-time, there are questions over whether there will be enough capacity. "It's going to be more difficult at the beginning," said the UK's chief scientific adviser Patrick Vallance in a 28 May press conference, because case numbers will be higher.

The programme is "currently far from being the robust operation that is now urgently required", said the ADPH.

There were 2872 deaths involving covid-19 in the week ending 22 May, according to provisional figures from the ONS, with the total number of UK deaths nearing 50,000.

Across the Atlantic, the US this week passed the grim milestone of more than 100,000 deaths, and anti-racism protests following the killing of George Floyd are raising concerns over further transmission of the coronavirus.

From the start, the US has been pursuing a programme of contact tracing, with the 130 "disease detectives" of the Centers for Disease Control and Prevention (CDC) focusing on states with low case numbers and high-risk places such as prisons. The agency has been working to scale up tracing capacity in each state by drawing on local public health officials, says Eric Pevzner at the CDC. ▮

Daily coronavirus news round-up
Online every weekday at 6pm BST
newscientist.com/coronavirus-latest

Death toll

How it all went wrong in the UK

The UK's handling of testing, contact tracing, protective equipment and lockdown have left it with one of the highest death rates in the world, reports **Adam Vaughan**

THE UK has been a leader in its coronavirus response, but not in a way any government would aspire to. The country now has the highest absolute excess deaths in Europe, 59,537 more than usual since the week ending 20 March, and the second highest per million people, behind only Spain for countries with comparable data, according to a *Financial Times* analysis. The total number of confirmed covid-19 deaths when *New Scientist* went to press was second only to the US, and was still rising by more than 100 a day.

"Not knowing they were infected, many people were carrying on as normal and infecting others"

"I think it's nothing short of a disgrace, and a dereliction of duty," says former UK chief scientific adviser David King about the figures, which are coupled with more than a quarter of a million lab-confirmed cases.

King, who last month launched an independent alternative to the government's scientific advisory group, says that while differences in culture, demographics and data collection can make international comparisons hard, they cannot explain the gap between the UK and countries including Australia, Greece and South Korea.

Playing catch-up

"You've got an enormous disparity. I don't believe the reason is any other than the actions taken by the government very early on," says King. Ministers' focus on other issues meant they failed to act in February and March, he says.

This view is shared by infectious disease and public health experts. "We have been playing catch-up from the start," says Helen Ward at Imperial College London. She cites slowness on testing, tracing and isolating people, and on social distancing. A national lockdown wasn't imposed until 23 March, about two months after the country's first confirmed case.

Neil Ferguson at Imperial, who was a member of the government's science advisers, the Scientific Advisory Group for Emergencies (SAGE), until early May, says that while the high number of deaths is partly down to the UK being so connected to the rest of the world, speed was also a factor. "Part of it is clearly down to implementing lockdown relatively later than other countries did," he says.

Why the UK was so late to lockdown isn't clear. Ferguson says it may have been down to a lack of insight due to limited testing. "Surveillance in hospitals only really stood up in the second week of March," he says. "Before that, we didn't really have a good handle on the scale of the problem."

STEVE FORREST/PANOS PICTURES

A woman and carer in Manchester during the UK lockdown

59,537
more deaths than usual in the UK since the week ending 20 March

12,739
care home deaths involving covid-19 in England and Wales

300
Number of Public Health England contact tracers early in the outbreak

Testing levels are now fairly high, but Conservative MP Greg Clark, chair of the House of Commons science and technology committee, has described them as "inadequate for most of the pandemic". The bottleneck seems to have been the government's decision to rely on a small number of centralised laboratories run mostly by Public Health England (PHE), rather than involving the UK's many private labs, research institutes and universities. The decision was "one of the most consequential made during this crisis", Clark said.

Yvonne Doyle at PHE has said that tests could at first be done only by labs rated as category level 3, the second highest in the UK's biosafety standards. "That meant very few laboratories initially could do that," she told the science and technology committee on 22 May. On 1 March, regulations were relaxed to allow some work to be carried out by level 2 labs, which Doyle says was key to increasing capacity.

That doesn't seem to be the full story, given anecdotal reports that offers of help from labs rated level 3 weren't taken up. "Since the earliest days of the epidemic, I've been trying to supply help for testing and generally getting nowhere," says Richard Wheeler, who runs a level 3 lab at the University of Oxford. He says about four email chains to PHE received no response.

Paul Nurse at the Francis Crick Institute in London said its own offers to test went without clear answer for weeks. "It was a little like pass the parcel," he said of the government response.

Health Check newsletter
A round-up of the latest health news every month
newscientist.com/healthcheck

To contain an infectious disease, testing must go hand-in-hand with contact tracing. But in the early days of the UK outbreak, PHE had fewer than 300 people doing contact tracing, and stopped tracing cases in the community on 12 March, focusing instead on specific places such as prisons. Minutes of a SAGE meeting on 18 February show that PHE only had the capacity to "cope with five new cases a week", and there was agreement that tracing should stop when the virus was widely spreading. "When there is sustained transmission in the UK, contact tracing will no longer be useful," said the minutes, which were made public last week.

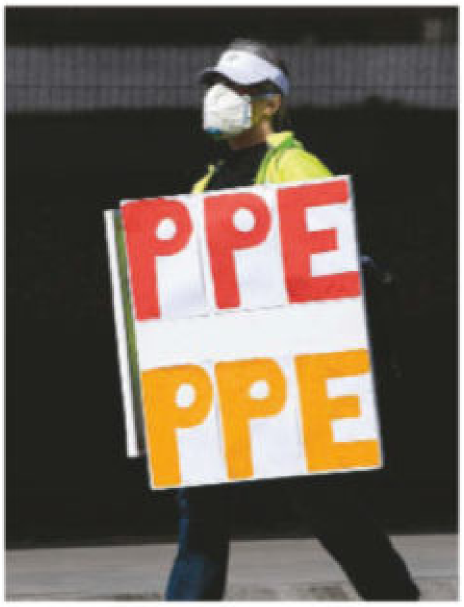
Slow on symptoms

Gabriel Scally at the University of Bristol, UK, describes the suspension of tracing as "the single greatest mistake". Although London had a high incidence of cases then, he says, other parts of the country didn't and tracing could have made a difference.

Ward believes the decision was due to a lack of public health experts advising the government through SAGE and other avenues. Scally says that only one of the UK's four chief medical officers had a background in public health, despite it traditionally being a prerequisite for the role.

One bright spot has been that NHS intensive care and ventilator capacity were built up quickly and the system wasn't overwhelmed, says Ward. "Our strategy has been designed at all times to protect our NHS and save lives," a Department of Health and Social Care spokesperson told *New Scientist*. "Our response has ensured that the NHS can provide the best care possible for people who become ill, enabled hospitals to maintain essential services and ensured ongoing support for people ill in the community."

A woman in London protests about a lack of protective equipment in early April



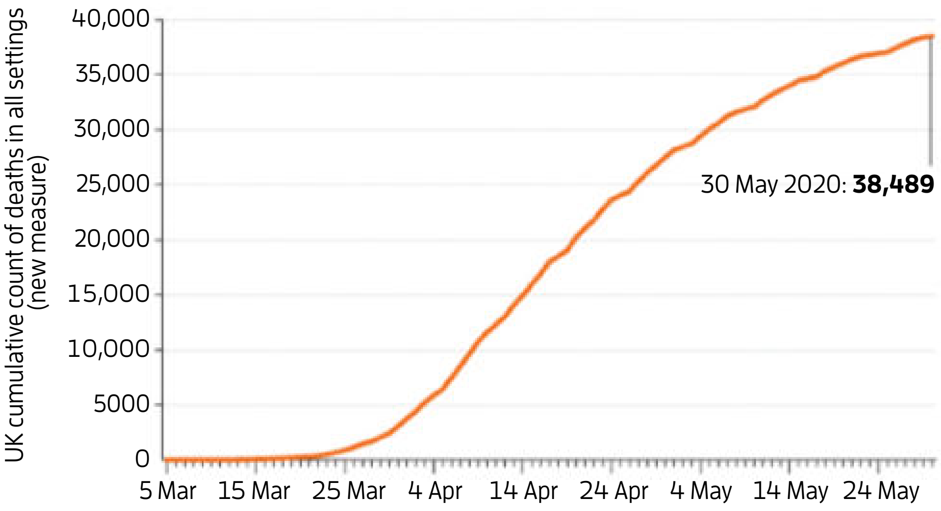
JUSTIN SETTERFIELD/GETTY IMAGES

Nonetheless, the outbreak has taken a toll on healthcare professionals, says Tom Wingfield at the Liverpool School of Tropical Medicine in the UK – on the hundreds who have died, and in fatigue and stress of staff too.

Personal protective equipment (PPE) has often been in short supply for health workers, something Scally blames on the UK being "late into the market" to buy more. And Wingfield says communication on PPE from the government to health professionals has at times been "confused or confusing".

After hospitals, most covid-19 deaths have been in care homes. Provisional figures suggest there had been 12,739 deaths involving covid-19 in care homes in England and Wales by 22 May. "I think in common with other countries, we have failed the population in care homes," says Ferguson, who believes more testing could have stopped the virus entering them. Patients discharged from hospitals to care homes were only routinely tested in England from mid-April.

The number of UK deaths attributed directly to covid-19



SOURCE: DEPARTMENT OF HEALTH AND SOCIAL CARE AND PUBLIC HEALTH ENGLAND

The UK has also been much slower than some countries in telling people what covid-19 symptoms to look out for, with a heavy focus on cough and fever. The virus has been linked to many other symptoms, including sore throat, runny nose, headache, vomiting and diarrhoea. A loss of taste and smell was added to the UK's list of symptoms on 18 May, more than a month later than in France.

"We are behind nearly every other country in the world," says Tim Spector at King's College London, which has 3 million people signed up to its covid-19 symptom tracking app. About 37 per cent of app users who reported a positive swab test hadn't had fever or a cough – the only two symptoms the UK government said required self-isolation until loss of taste and smell were added to the list months later. "Many people, by not knowing they were infected and not being told [the other symptoms], were carrying on their normal business and infecting other people," says Spector.

A new contact tracing scheme for England launched on 28 May, and the UK is now relaxing some lockdown restrictions, particularly in England where the number of daily new infections remains high.

Scally says the public's adherence to restrictions has been exceptional so far. However, King fears that may be undermined by potential breaches of guidance by the prime minister's adviser, Dominic Cummings. "The potential is many people will take less seriously further public health messages from the government. I fear the moral authority has been lost," he says.

> **"The highest avoidable death toll in Europe tells us we have not done well, but there's no admission of it"**

Given the unprecedented nature of the epidemic, Scally says any government would have made poor decisions at times, but "never have they admitted they got anything wrong, or said they are sorry for an action or inaction".

"Having the highest avoidable death toll in Europe tells us this was not done well," says Scally. "You can't do well in the future unless you're prepared to look back and see what worked and didn't work." ▮

Vaccine development

Countdown to a vaccine

More than 100 coronavirus vaccines are in development, but will any of them work?

Michael Le Page

NICOLAS ASFOURI/AFP VIA GETTY IMAGES

An engineer tests an experimental vaccine in Beijing, China

JUST months after the coronavirus pandemic began, 10 vaccines designed to prevent covid-19 are already being tested in people, and another 114 are in development.

A vaccine that provides effective, long-lasting protection against the coronavirus would be a game-changer, far better than any treatment. "Do we need a vaccine? Absolutely we do. It's really better to prevent," says Peter Horby, who is leading a UK trial evaluating several covid-19 treatments.

However, we don't yet know whether it is possible to induce long-lasting coronavirus immunity with a vaccine. When people are infected by other kinds of coronaviruses, their immunity seems to fade rapidly – although subsequent infections are milder. There are concerns this could mean that any protection from a vaccine would fade too. "It may be that we don't get a one-dose vaccine that lasts for a lifetime," says Martin Hibberd at the London School of Hygiene & Tropical Medicine.

A vaccine that ensures people only become mildly ill would still be good, says Hibberd. "We would be pretty happy with that."

Vaccines work by teaching your immune system to recognise part of a pathogen. There are a variety of ways to do this and just about every approach is being tried for the coronavirus.

Four of the 10 already being tested in people are inactivated vaccines, which administer the coronavirus in a chemically inactivated form that is unable to replicate. Another of the front runners is a subunit vaccine, consisting of the spike protein on the outside of the coronavirus, which the virus uses as a key to gain entry to our cells.

Inactivated and subunit vaccines tend not to provoke a big immune response, so chemicals often have to be added to boost their effects. Many vaccines we use today are one of these two types, including many flu vaccines.

The other five front runners use various methods – such as fatty droplets or the shell of another virus – to deliver genetic code for a viral protein, such as the spike protein, to human cells. This RNA or DNA code is then used by the cells to make the protein. Using DNA or RNA for vaccines in this way is a relatively new idea, and none has yet been approved for any disease.

10
experimental vaccines are already being tested in people

None of the coronavirus vaccines currently in trials are live attenuated vaccines. This kind of vaccine uses a mutated version of the virus that is only capable of causing very mild disease, if any symptoms at all, and is the method used for many of the most effective vaccines we have, including the measles, mumps and rubella vaccines that are usually given together. Two groups in India are working on live attenuated coronavirus vaccines, but experimental vaccines of this kind have a higher risk of giving people covid-19, so it will be a while before human trials are ready to begin.

So far, the 10 experimental coronavirus vaccines that have been tested in people appear safe, based on the preliminary announcements from several teams, the fact that none of the trials have been stopped by regulators yet and one published peer-reviewed study (*The Lancet*, doi.org/dwjd).

For a few, there have also been studies of vaccinated people's immune response, or tests to see if vaccinated animals are protected. These early results, most of which haven't yet been published, suggest that these vaccines could provide at least some protection, although they have many further tests to pass yet.

Short-lived protection?

It is still far too early to pick a winner, says Danny Altmann at Imperial College London, who says different experimental vaccines will have different strengths and weaknesses. Some might not work as well in older people, for example, or provide only short-lived protection. "We need all of these contenders," says Altmann. "We don't want the first, we want the best."

The only way to find out for sure how well these vaccines work is to give them to thousands of people of all ages. A University of Oxford team trialling a vaccine that uses the gene for the spike protein inside a viral shell is now expanding its initial trial of 1000 people to 10,000 people, including children and people over the age of 56. It is at this second, larger stage of human trials that vaccines usually fail, says Hibberd.

It can also take a long time to get results – and the falling numbers of new coronavirus infections in many countries will make it harder. As outbreaks decline, vaccinated volunteers are less likely to be exposed to the virus, providing less opportunity to see if it works.

This has led to proposals to deliberately infect vaccinated volunteers, to speed up the trial process. Such "human challenge" trials would be controversial because we have no effective treatments for covid-19 yet. If the experimental vaccine doesn't work, volunteers could die.

Advocates of the idea, such as bioethicist Nir Eyal at Rutgers University in New Jersey, argue that such trials are acceptable if they involve young volunteers with no known health conditions who have a high risk of getting coronavirus. For the average person in their twenties, the risk of dying from covid-19 is less than 1 in 3000. The idea seems to be gaining momentum, with more than 26,000 people worldwide volunteering via the website 1daysooner.org, but it remains to be seen if any country will allow such trials. "At this point, I would put it only a bit over 50-50 in favour of challenge trials," says Eyal.

Such trials wouldn't reveal whether an experimental vaccine protects the most vulnerable, however. And if you want to know whether immunity lasts for, say, a year, a trial would have to take at least that long.

Even if trials do find effective vaccines, the immense challenge of making enough doses for up to 7 billion people will be a big bottleneck. This is true even for those vaccines for which manufacturing capacity is already being created before it is even clear if they work.

No one can predict how quickly a vaccine could be made. Some kinds are much harder to manufacture than others, says Altmann, and there can be unexpected hiccups that hold up production. For instance, there is currently a global shortage of the glass vials used to store vaccine doses.

Treatment

Ventilators may not be best for severe covid-19

Clare Wilson

WHEN the coronavirus pandemic began, the UK scrambled to get more ventilators for use in intensive care. But now some doctors are trying to keep people off ventilators, as they believe it makes some people with covid-19 worse – although we don't have the results of studies to assess this yet.

Ventilators are used to treat people with covid-19 who have difficulty breathing on their own, but the procedure is invasive and can even be traumatic. Doctors have other, less invasive, options, including giving patients oxygen by face masks or nasal cannulas, two tubes that sit just inside the nostrils.

Those with severe infection may need to be put on a ventilator, which usually requires a patient to be unconscious so a tube can be put down their throat. But this carries risks, and recovery can take weeks or even months.

Initially, people taken to hospital with breathing difficulties due to covid-19 were quickly being put on ventilators. This was partly because of anecdotal reports from China that people given face masks and nasal cannulas often deteriorate and need ventilation anyway, says Stephen Brett at Imperial College London.

As doctors have gained more experience with covid-19, some now argue against being too quick to ventilate. One factor has been the high death rate in covid-19 patients put on ventilators, which has been more than 50 per cent in the UK.

"There's a belief among some that some people can be supported non-invasively"

"The success rate reported from Italy and New York was very low," says Michael O'Connor, who heads critical care at the University of Chicago Medicine. He believes, based on the patients he has treated, that the high air pressures used in ventilation could be worsening lung damage.

Concerns are also lessening that face masks and nasal cannulas spread infections. It had been thought that they blow more virus into the air than ventilators. "People are now feeling that the cross-infection risk is manageable," says Brett. "There's a belief among some that there's a population of people who can be supported non-invasively, but there are some institutions that remain sceptical."

There are no figures on which approach is being used the most, but ongoing trials should answer the question, says Matt Morgan at the University Hospital of Wales in Cardiff. "Should we use [ventilation] only at the very end, when the patient is about to stop breathing, or intervene earlier? You don't want to do it in the heat of the moment. Until we have trial results we do not know what the best thing to do is."

Earlier this year, there was concern over how the UK could source more ventilators. The UK had about seven intensive care beds per 100,000 people, compared with 12 for Italy and France, and 30 in Germany.

The UK government told ventilator manufacturers to increase production and placed a provisional order for 10,000 machines from the firm Dyson. This has since been shelved as demand for ventilators has been less than initially predicted.

Hospitals in the UK raised their intensive care capacity by cancelling non-urgent surgery and using ventilators from operating theatres, and some extra machines have been bought from abroad.

Brett says some of the manufacturers' new, simpler designs may be useful for low-income countries. "There has been some very useful engineering done," he says.

JON SUPER/AP/SHUTTERSTOCK

Part of a ventilator at a site focused on increasing production

Space flight

Launching into a new era

For the first time, a private rocket carried astronauts into orbit

Leah Crane

HISTORY has been made. On 30 May, SpaceX and NASA launched two astronauts into space aboard the Crew Dragon spacecraft, the first time a private company has flown humans into orbit, and the first crewed launch from the US since the end of the space shuttle programme in 2011.

"This is the first time that SpaceX has ever launched astronauts, and it's also the first time that a government has trusted a commercial company to launch astronauts to orbit," says space consultant Laura Forczyk. "It is a big deal."

The launch was initially set to take place on 27 May, but poor weather caused it to be delayed. By the 30 May backup date, the weather had cleared and NASA astronauts Bob Behnken and Doug Hurley successfully lifted off and headed to the International Space Station (ISS).

It took the Crew Dragon spacecraft about 19 hours to reach the ISS. The spacecraft docked with the station autonomously, but before they arrived, Behnken and Hurley had a chance to fly the capsule manually as a test.

"It flew just like it was supposed to," said Hurley after the astronauts arrived at the ISS. "It is exactly like the simulator and we couldn't be happier about its performance."

Now that they are safely aboard the ISS, Behnken and Hurley will continue to perform tests on Crew Dragon. They will remain on the ISS for between one and four months, joining the three astronauts already there in conducting scientific experiments, before returning to Earth using the Crew Dragon.

As the Falcon 9 rocket carried the Crew Dragon into orbit atop a plume of flames, it marked a new era of human space flight. "I've heard that rumble before, but it's a whole different feeling when you've got your own team on that rocket," said NASA administrator Jim Bridenstine after the launch. Now that SpaceX can carry humans to the ISS, NASA will no longer have to purchase seats aboard the Russian Soyuz spacecraft, and will have much more flexibility in sending astronauts to space.

NASA

Bob Behnken and Doug Hurley (right) join the crew of the ISS

A flight aboard the Crew Dragon is also less expensive than other crewed launches. "This is absolutely opening the doors for more people to go to space," says Forczyk. "In the future, SpaceX could open it up to private astronauts, whether that's for commercial space tourism, or Tom Cruise going to film a movie, or another government that doesn't have the capability to launch astronauts itself."

This is a big step towards making space flight more of an everyday phenomenon, and maybe eventually allowing ordinary people to visit space, said NASA astronaut Leland Melvin during a live webcast of the launch.

"We've had people that paid their way on a Soyuz rocket to go, but it's really the billionaire boys' club," he said. "It costs so much money to go to space, and I think that price point will come down as we start to make that more amenable for everyday people."

Genetics

Modern humans get fertility boost from Neanderthal DNA

NEANDERTHAL DNA carried by some people living today appears to reduce the chance of miscarriage and promote fertility. The finding is the latest evidence that *Homo sapiens* benefitted from sexual encounters with other species.

Genetic studies suggest anatomically modern humans interbred with Neanderthals on several occasions, and that people of non-African descent carry about 1 to 2 per cent Neanderthal DNA.

Some of this DNA is probably useful, but it can also be harmful. In 2018, Jingjing Li at Stanford University and his colleagues were studying the *PGR* gene, which plays a role in pregnancy, and realised a form, or allele, of the gene that increases the chance of premature birth contains Neanderthal DNA.

The finding puzzled Hugo Zeberg at the Max Planck Institute for Evolutionary Anthropology in Leipzig, Germany. Any harmful Neanderthal DNA that entered the modern human gene pool should have disappeared with time, as it left carriers at a disadvantage. But in some modern populations, the *PGR* Neanderthal allele is carried by about 20 per cent of people.

Zeberg and his team examined data from the UK Biobank, which includes the genetic and lifestyle information of more than 450,000 people. They found that women who carry the *PGR* Neanderthal allele were less likely to have experienced a miscarriage or unexpected bleeding during early pregnancy (*Molecular Biology and Evolution*, doi.org/ggxb4h).

This puts Li's finding in a new light. Zeberg speculates that some of these premature births would have been miscarried if the woman lacked the *PGR* Neanderthal allele.

Colin Barras

"Women who carry the Neanderthal allele were less likely to have experienced a miscarriage"

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Palaeontology

Ancient worms could be the original parasites

Michael Marshall

HUNDREDS of fossilised animals seemingly covered in worm-like creatures are the oldest hard evidence of parasitism, dating from 512 million years ago when complex animals were still new.

"We're documenting the oldest case of parasitism in the fossil record," says Timothy Topper at Northwest University in Xi'an, China. The discovery suggests that the first parasites arose during an unprecedented evolutionary flowering.

Zhifei Zhang, also at Northwest University, has spent years excavating a quarry in Yunnan province in southern China. The rocks preserved an ecosystem from the Cambrian period. This era saw the first complex animal life, such as the first arthropods, which include insects, and echinoderms, which include starfish.

Zhang's team found hundreds of fossilised brachiopods, animals with two shells resembling those of clams, called *Neobolus wulongqingensis*. The soft animal inside the shell has a tentacle that generates a water current to suck in food particles.

Many of the brachiopods had tube-shaped objects attached to them: sometimes one or two, but in other cases more than a dozen. These are the fossilised remains of hard tubes that once encased animals. These animals aren't preserved, but they were probably worm-like.

Evidently these animals lived with the brachiopods, but was it a cooperative relationship or a parasitic one? If the worm-like creatures were parasites, brachiopods that hosted them should have been less healthy than those without them.

"We took a whole bunch of measurements of the sizes of the shells of the brachiopods," says team member Luke Strotz. "Those that didn't have tubes were larger overall." This suggests that the wormlike creatures were parasites (*Nature Communications*, DOI: 10.1038/s41467-020-16332-3).

"The worm-like creatures may have stolen the brachiopods' food as it was sucked in"

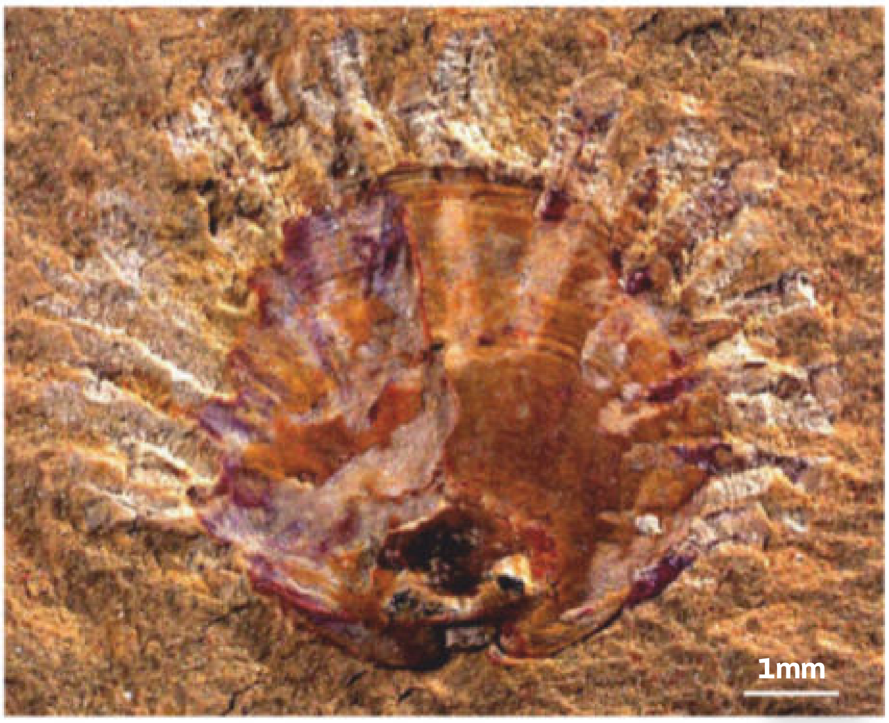
"This looks like it is a host-parasitic relationship," says Xiaoya Ma at Yunnan University in Kunming, China, who has previously found evidence of Cambrian parasitism. She says the huge number of animals studied makes the finding "very sound".

"We also found that the orientation of the tubes all seemed to be consistent," says Strotz. "The alignment of the tube preferentially aligns with the feeding intake of the brachiopods." This suggests the worm-like creatures were "kleptoparasites" that stole the brachiopods' food as it was sucked in by their tentacles.

Strotz also argues that they were obligate parasites, meaning they couldn't survive without their hosts, but Ma says there isn't enough evidence. "We don't know what this tube-dwelling organism is," says Ma.

It isn't clear whether the creatures are some of the first animal parasites, or if there were older examples that haven't been fossilised. However, Topper and Strotz say that a Cambrian origin for parasites would make sense. As well as the appearance of many new animal groups, the period saw animals evolve new behaviours, from hunting to burrowing.

This may have been driven by a rise in oxygen levels, which increased animals' metabolic rates and let them try out new ways of finding food, says Strotz.



Brachiopod fossils found in China show signs of parasites

ZHIFEI ZHANG (NORTHWEST UNIVERSITY)

Humans

Grey hair can regain its old colour in times of reduced stress

Alice Klein

PEOPLE'S grey hairs sometimes naturally regain their original hue, typically when individuals feel less stressed. The finding suggests that it may be possible to develop drugs to tackle greying.

It has long been assumed that once hairs turn grey, they stay that way. But Martin Picard at Columbia University in New York and his team discovered by chance that hair greying can go into reverse.

They looked at 14 healthy men and women from different ethnic backgrounds with an average age of 35, plucking 397 hairs from the participants and studying them under a microscope. They identified greying hairs by looking for those that were grey at the roots while still coloured at the tips, because new hair grows from the scalp.

To their surprise, the researchers discovered some hairs with the opposite pattern – they were coloured at the roots and grey at the tips – suggesting they were reverting to their original colour.

Because hair grows at a fixed rate, the team was able to trace these colour transitions back to specific life events. The reversals tended to correlate with periods of reduced stress. For example, it occurred in one participant when he went on a two-week holiday and in another after she recovered from the stress of her marriage breakdown (bioRxiv, doi.org/dw3d).

This probably only occurs in a few scattered hairs, says David Fisher at Harvard University, since we would have noticed if people's full heads of grey hair changed colour when they felt less stressed. "Perhaps there is a discreet subset of grey hairs that can do this," he says.

If we can uncover the biological mechanisms underpinning reverse greying in these few hairs, we may be able to develop drugs that stimulate anti-greying across all hairs, says Fisher.

Cybercrime

US voter data sold on dark web

Illegally gathered voter registration information could be used to influence elections

Chris Stokel-Walker

USA TODAY NETWORK/SIPA USA/PA IMAGES

Voters in the South Carolina Democratic primary in February

DATA on millions of US voters is being illegally traded on the dark web as the US is gearing up for the 2020 presidential election. The data could be used to attempt to influence voters.

The dark web is a part of the internet not searchable using normal means. It is encrypted and visible only through specialist web browsers that anonymise data transfers, and it is a thriving marketplace for illicit material.

Cybersecurity firm Trend Micro has analysed 600 dark web forums dealing in underground trading. The firm found that databases of US voter information, containing names, addresses and political affiliations, could be bought for $9.99 or less – a fraction of the going rate on the dark web of $26 for 1000 fake YouTube likes, which some people buy to boost their popularity on the video site.

Voter information is cheaper because clicking YouTube's like button requires a human or a bot, which cost money, says Mayra Rosario Fuentes at Trend Micro, and voter databases age and depreciate in value.

Information from other nations can cost more – the highest price Trend Micro saw was $400 for a Turkish voter database. That is because, unlike the US, most countries don't publicly publish information about their voters.

"In the US, some of this information is available for free at a state-wide level," says Rosario Fuentes. "If it's harder to obtain the information, they're going to charge more."

Access to US voter registration lists varies by state. Generally, political parties can view redacted versions of the lists for free, but other organisations or individuals must pay a fee or visit a local government office in person. That can make buying an electronic version on the dark web attractive.

There have been a number of high-profile hacks of voter data. In 2017, more than a terabyte of voter data, covering 62 per cent of the US population, was taken from an unsecured server operated by a firm called Deep Root Analytics. Rosario Fuentes says this data is being sold on the dark web. Deep Root Analytics declined to comment for this article.

The Philippines's election commission and the Turkish government both had voter data breaches of around 50 million individuals each in 2016, and this data is also being traded, according to Trend Micro. The Philippines's election commission and Turkey's justice department didn't respond to requests for comment.

"Citizens are worried that their country's election can be interfered with," says Rosario Fuentes. Recent votes, including the 2016 US presidential election and the UK Brexit referendum, have seen accusations of interference through the use of bots and other social media exploits.

The data being traded on the dark web could be used for this purpose. "If you have a database where you can in some way infer the ideology of someone, carrying out a disinformation campaign would be easier," says Yevgeniy Golovchenko at the University of Copenhagen in Denmark. ▮

Cosmology

Ancient magnetic fields may have shrunk Milky Way

MAGNETIC fields present in the early universe may have reduced the volume of our galaxy by nearly 30 per cent. These fields seem to concentrate matter in the centre of galaxies, which might help explain why some black holes in such locations grow so fast.

Sergio Martin-Alvarez at the University of Cambridge and his colleagues simulated the effects of primordial magnetic fields on galaxy formation.

Computer simulations of galaxy formation don't usually take these fields into account, says Martin-Alvarez. "It's a very important parameter that is often overlooked because it is so hard to understand theoretically," he says. "But it could change potentially everything we know about the early stages of the universe to even modern day."

By simulating a galaxy with a similar size, shape and conditions to those of the Milky Way, the team found that removing the primordial magnetic fields let the galaxy's volume grow about 45 per cent larger than it would have otherwise (arxiv.org/abs/2005.10269).

These magnetic fields may have shrunk galaxies in the early universe by packing gases into a smaller space during galaxy formation.

45%

Without magnetic fields, the Milky Way would have been this much bigger

This may also help explain why supermassive black holes are often found at the centre of galaxies and why they grow so fast, says Martin-Alvarez. "If a galaxy is concentrated at its centre, you have more material to feed into a black hole, and so you can grow its mass very quickly," he says.

"[This work] gives some tentative picture of when the effects of magnetic fields might become important," says Andrew Jaffe at Imperial College London. ▮

Jason Arunn Murugesu

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Official fuel consumption figures for the Golf model range in mpg (litres/100km): Combined 44.8 (6.3) – 68.9 (4.1). Combined CO_2 emissions 142 – 108 g/km. Figures shown are for comparability purposes; only compare fuel consumption and CO_2 figures with other vehicles tested to the same technical procedures. These figures may not reflect real life driving results, which will depend upon a number of factors including the accessories fitted (post-registration), variations in weather, driving styles and vehicle load. Data correct at 04/20. Figures quoted are for a range of configurations and are subject to change due to ongoing approvals/changes.

Health

Gut-brain link hints at route to treat Parkinson's disease

Jessica Hamzelou

PARKINSON'S disease may start in the gut and travel to the brain – but it can also spread the other way.

Previous research has suggested that the misfolded proteins that characterise the disease may spread from the gut to the brain, but much of this work has been done in mice.

To get a better idea of what might be happening in humans, Benjamin Dehay at the University of Bordeaux in France and his colleagues studied baboons of various ages, equivalent to a range between human teens and middle-aged adults. They took misfolded alpha-synuclein – thought to trigger brain damage in people with Parkinson's – from donated brains of people who died with the disease, and implanted it into either the guts or brains of 10 baboons.

Two years later, there was protein in both the brains and the guts of all the baboons given it, regardless of where it had been implanted. All these animals also showed signs of brain damage and had lost around 40 per cent of their dopamine-producing cells in a region of the brain key to movement (*Brain*, doi.org/dw65).

The gut-brain link in Parkinson's disease may be connected to the vagus nerve, which runs all the way from the brain to the abdomen. But Dehay and his team couldn't find the misfolded protein in this nerve. Instead, they found it in the baboons' blood, suggesting it may travel via the bloodstream.

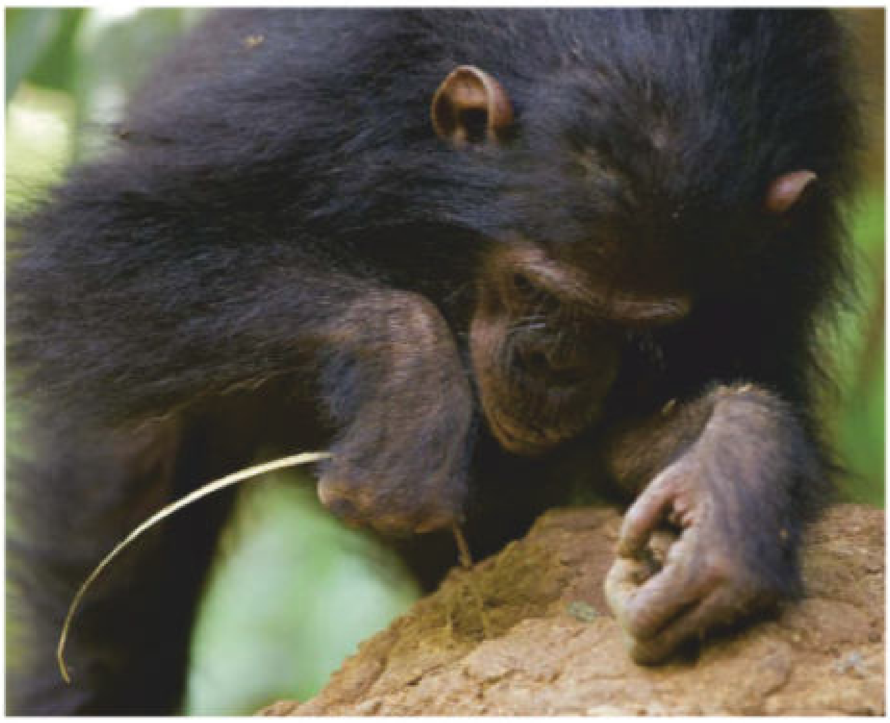
Denise Barbut, a neuroscientist at biotechnology firm Enterin, isn't so sure. Research in rodents has shown that alpha-synuclein can travel along the vagus nerve in a matter of days. The protein may have left the vagus nerve by the time the team looked two years later, she says.

Even so, Barbut thinks this two-way spread is happening in humans. She is investigating a potential Parkinson's disease treatment targeting the gut. ▮

Animal behaviour

Chimps adapt to fit in with the local dining culture

Rowan Hooper



MINDEN PICTURES/ALAMY

A juvenile chimp hunting for termites with a stick

HOW many ways are there to get a termite to run up a stick? A surprising variety, it turns out. A new analysis of how chimpanzees perform this "termite fishing" has revealed that different groups of the primates have distinct dining cultures, similar to how the way humans use chopsticks differs across the world.

The idea that non-human animals can even have human-like cultures – behaviours and social norms that vary by group – has been controversial. But this study firms up the idea that chimp ethnography, the study of chimp culture, is a viable subject.

Carel van Schaik at the University of Zurich, Switzerland, who wasn't involved in the research, says the work confirms beyond any doubt that the variation that has been found among chimps is cultural. "This paper is an absolute milestone in 'culture in nature' research," he says.

Christophe Boesch at the Max Planck Institute for Evolutionary Anthropology in Leipzig, Germany, and his colleagues chose to study termite fishing because it is widespread, allowing them to make lots of observations in different groups.

The researchers set up camera traps in 39 different wild chimp communities to record them eating termites, which they saw in 10 of the groups. It may be that the other communities didn't have enough termite mounds in the area to display the behaviour, or perhaps simply that the cameras didn't happen to capture any termite fishing.

> "Neighbouring chimp communities differ in their termite-fishing techniques"

They noted each element of the termite-fishing behaviour from hundreds of video clips to create a behaviour profile for each chimpanzee in the study. It turns out there are 38 different technical elements to the practice, all used in different combinations in each community (*Nature Human Behaviour*, doi.org/dw2x).

Individuals in the same community used more similar techniques compared with chimpanzees from other groups. In other words, there were local cultural differences. "As in human social conventions, you do it as you see others do," says Boesch.

Chimpanzees in Korup National Park in Cameroon, for example, lean on their elbows to insert sticks into termite mounds and then shake the sticks with their mouths to get the termites to bite. Meanwhile, chimpanzees in the Wonga Wongué National Park in Gabon lie on their sides and insert the sticks without shaking them. When extracting the sticks, they take the termites directly off them with their mouths.

Van Schaik says the study also raises the intriguing possibility of chimp etiquette. Boesch and his team found that neighbouring chimp communities differ in the details of their fishing techniques, even though the groups exchange members.

It seems that the differences aren't functional, in that some methods work better in one place than another, but cultural, and that chimps moving to a new community change their methods to fit in with their new social group and hasten social acceptance and integration. We don't yet know whether the chimps feel pressure to conform or if there are punishments or sanctions for nonconformity, says van Schaik. ▮

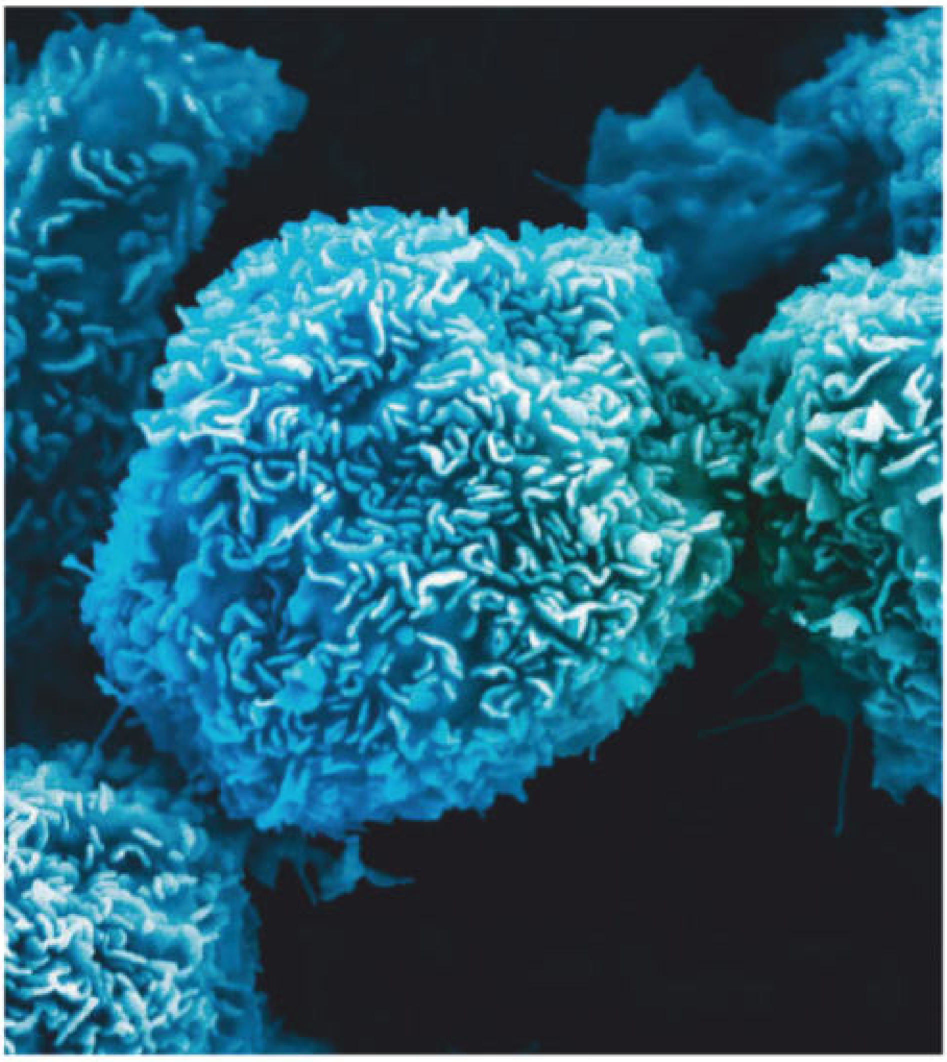
Palaeontology

Dinosaurs sometimes ate their own kind

BITE marks on Jurassic dinosaur bones show that allosaurs resorted to cannibalism.

Stephanie Drumheller at the University of Tennessee, Knoxville, and her colleagues studied 150-million-year-old fossil bones from the Mygatt-Moore quarry in Colorado. Normally only the best bones get studied, but her team collected every bone found there. Nearly 30 per cent of the 2368 bones had bite marks on them (*PLoS One*, doi.org/dw26). Usually less than 5 per cent do.

The team thinks most of the bite marks were made by allosaurs: the most common large predator found at the site. Many bite marks were found on the bones of other allosaurs. It could have been from scavenging or cannibalism. Why these may have been common at the site is unclear. **Michael Le Page**



ANNE WESTON, FRANCIS CRICK INSTITUTE/SCIENCE PHOTO LIBRARY

Cosmology

Strange radio signals reveal hidden matter

MYSTERIOUS signals called fast radio bursts are helping pin down the universe's missing matter.

There should be twice as much normal matter as we have so far been able to see. Now, Jason Prochaska at the University of California, Santa Cruz, and his colleagues have used the Australian Square Kilometre Array Pathfinder radio telescope to monitor bright flashes of radio waves coming from space. Each of the fast radio bursts was slightly spread out and delayed when it arrived, with higher frequencies arriving before lower ones (*Nature*, doi.org/dw28).

The team says the dispersion and delays must be due to missing matter between galaxies slowing the bursts. "The more material you travel through, the greater the dispersion," says Prochaska. **Jonathan O'Callaghan**

Cancer

Bacteria found living inside a huge range of tumours

THE first comprehensive survey of the microorganisms that live inside tumours has found that bacteria reside in many cancer types. It is unclear whether they contribute to tumour growth.

These bacteria make up part of a tumour's microbiome: the complex community of bacteria, fungi and other microbes that live inside it.

Bacteria have previously been found in tumours in the bowel and other tissues in the body that are routinely exposed to microbes.

Ravid Straussman at the Weizmann Institute of Science in Israel and his colleagues wanted to look for bacteria in other tumours. They examined more than 1000 samples collected from people with cancers of the bone, brain, ovary, breast, skin, pancreas or lung at nine medical centres in four countries.

The team found bacteria in tumours from all cancer types, although to differing extents. More than 60 per cent of bone, breast and pancreatic tumours tested positive for bacterial DNA, compared with only 14 per cent of melanomas.

In total, 528 species of bacteria were detected. A different mix of species was found in each tumour type, with those from breast cancer harbouring the most diverse range.

It is unclear why different bacteria colonise different tumours, but exposure to environmental factors that cause cancer may play a part, says Straussman. For example, lung tumours in smokers tended to contain bacteria that break down tobacco chemicals (*Science*, doi.org/ggxqh4).

Bacteria may contribute to tumour growth, or they may simply find it easier to invade tumours than ordinary tissue, says Straussman. **Alice Klein**

Really brief

CEDUARDO ESQUECHE LARRABURE

Speakers create Braille in mid-air

People who are blind can read Braille in mid-air using speakers that emit ultrasound waves. The waves create an acoustic force that is perceptible on the palms. They are similar to the dots that form Braille characters. In a test, 11 people correctly identified 88 per cent of Braille characters (arxiv.org/abs/2005.06292).

Cannabis used in biblical-era ritual

Religious ceremonies thousands of years ago in what is now Israel involved burning cannabis, according to a study of an ancient shrine. It suggests psychoactive substances had a role in rituals in the biblical Kingdom of Judah (*Tel Aviv*, doi.org/dw2w).

3D model reveals time of death

Forensic scientists trying to determine time of death could have a new tool. A model that uses skin and air temperatures, body size and position, and details of any clothing to create a 3D simulation of the body is more accurate than simple temperature readings used today (*Science Advances*, DOI: 10.1126/sciadv.aba4243).

9 July 2020 6pm BST/1pm EDT

NEW ONLINE EVENT: WHAT HAPPENED AT THE BIG BANG?

Dan Hooper, Fermi National Accelerator Laboratory

Theoretical astrophysicist Dan Hooper reveals how little we know about the first few seconds after the big bang and why the early universe could soon give up its secrets

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Welcome to our Signal Boost project. In these difficult times, we are offering charitable organisations the chance to take out a page in *New Scientist*, free of charge, so that they can get their message out to a global audience. Today, a message from **In2scienceUK**

Its all change for outreach

The regulations on social distancing in the UK have caused the widespread closure of schools and higher education institutions, with much outreach work hindered. At a time when young people who are most disadvantaged need support and guidance more than ever, it is imperative that organisations small and large are innovative and use their resources to still make the difference, ensuring that the work on improving diversity and inclusion in the science, technology, engineering and maths (STEM) sector does not roll backwards.

In2scienceUK aims to empower disadvantaged young people to achieve their potential and progress to degrees, apprenticeships and careers in STEM. We have responded to the Covid-19 outbreak by moving our support online. With physical work placements this summer cancelled, we have launched a Virtual Placement Programme to preserve the benefits and ensure those in greatest need gain the support they need so much and which will pay dividends to their future.

MEET A SCIENTIST, TECHNOLOGIST, ENGINEER, MATHEMATICIAN!

Through working with partners including the National Institute for Health Research Biomedical Research Centre at University College London Hospitals NHS Foundation Trust, the programme offers a range of high level research-focused modules delivered by expert researchers. All students will explore STEM research beyond the classroom while developing research and employability skills and crucially their confidence. The highlight of the programme is being mentored by a STEM professional. The majority of young people taking part in the In2scienceUK programme do not have connections within the STEM sector and so lack positive role models and the opportunity to gain relevant work experience and advice on careers development. This programme matches each young person with a STEM professional to give them the support they need.

VOLUNTEER TO MAKE THE DIFFERENCE

In2scienceUK is looking for volunteers who would like to provide support to young people through mentoring. Volunteers will:

- Participate in two 45 minute mentoring sessions with a small group of up to five students.
- You will be matched with 3-5 students whose interests align with your work.
- The sessions will take place over the summer according to your availability, within blocks of times.

No prior experience is needed and all volunteers will receive training and a framework for each session. Mentoring sessions will be hosted through our online platform. By discussing your work and career pathway you can inspire the next generation of STEM professionals. To find out more please visit in2scienceuk.org

Do you need your signal boosted?

If you are a charitable organisation working in science, medicine, technology, education or conservation, and would like to find out more about this project contact Chris Martin on chris.martin@newscientist.com

Letters
Will the coronavirus pandemic affect our evolutionary path? **p22**

Aperture
Conservation efforts are under way to protect pangolins **p28**

Culture
The strange and mysterious world of mushrooms (and other fungi) **p24**

Culture
A new film explores the eclectic mix of people who visit Chernobyl **p25**

Columnist

Living life through a lens

Watching videos of different tasks being completed is oddly satisfying and reminds us of pre-lockdown life, says **Annalee Newitz**

Annalee Newitz is a science journalist and author. Their latest novel is *The Future of Another Timeline* and they are the co-host of the Hugo-nominated podcast *Our Opinions Are Correct.* You can follow them @annaleen and their website is **techsploitation.com**

IT STARTED innocently enough, with a friend telling me about the Peregrine Nest Cam at the University of California, Berkeley. High in the campus clock tower, under a webcam's watchful eye, some biology researchers had arranged a box of gravel for two peregrine falcons and their three floofy, awkward babies. I couldn't stop watching. I've spent weeks following along as the chicks shed their down, fought for chunks of meat and screamed at the top of their lungs. Now, they are almost ready to fly and I feel a deep sense of accomplishment.

But why? I didn't help these birds grow up, though I cheered for them remotely. Yet they are part of my life now. I have the falcon cam streaming to my desktop all the time, and I'm listening to two of the siblings squawk at each other as I write this. I can't figure out what makes it so compelling. So I asked Emily Anthes, author of *The Great Indoors*, who spent years studying the science of indoor life. She told me that our brains respond to images of nature as if we were actually outdoors, so perhaps the falcons are giving me vicarious enjoyment of the open skies.

Another possibility is that the falcon cam falls within a genre of online videos known as "oddly satisfying". Commenters on Reddit came up with the phrase to describe short videos of everything from gears meshing and robot arms sorting batteries, to people painting in exact strokes on a fence or pressing dough into tidy circles. You can find millions of videos with the hashtag #oddlysatisfying on social media, and Google reports that various subtypes of the genre have shot up in popularity during quarantine.

An early video compilation in this genre, called simply "The Most Satisfying Video in the World", has garnered more than 19 million views on YouTube since 2016 – which is pretty impressive for a compilation video that features taffy stretching and marbles rolling down a chute. Its creators define "oddly satisfying" as "something that makes your skin tingle and for some unknown reason provides you with a sense of unbridled peace and happiness".

> **"Put simply, escapism works best when it acknowledges the feelings we are trying to escape"**

Certainly that is the emotional state the falcons evoke, and not merely because they are cute. What the falcon cam shares with, say, a video of gears meshing is a sense of orderly progress.

The falcon cam is a way of experiencing the passage of time as a series of achievements: the samey days of quarantine blur into each other, but at least one thing is changing for the better. Those baby falcons are growing beautiful plumage, and by the time you read this they will be soaring in the hot California afternoons. #Oddlysatisfying videos give us the pleasure of task completion. That's why it is so fun to watch fast-motion clips of people building or cooking something from start to finish.

Media researcher Stefan Werning writes that #oddlysatisfying videos arouse two seemingly opposed emotions: vigilance and amazement. Vigilance, Werning explains, creates a strong sense of interest or anticipation, while amazement gives us an intense distraction or surprise. This might explain why the falcon cam and other #oddlysatisfying videos are so popular during quarantine.

Doomscrolling through the news is making us hyper-vigilant, so we may be drawn to entertainment that incorporates that sensation of vigilance while also deflecting it with amazement. Put simply, escapism works best when it acknowledges the feelings we are trying to escape.

When time has slowed to a terrifying crawl, we want to see simple representations of change: birds growing up, gears meshing, automated threshers harvesting. We want to remember what it is like to go outside and accomplish mundane things. And so we keep clicking, hoping the next video will be more satisfying than the last. ▮

Annalee's week

What I'm reading
John Marzluff's Welcome to Subirdia, *an ornithologist's exploration of wild birds that live among humans just outside large cities.*

What I'm watching
Upload. *It is the cleverest depiction of virtual reality that I've seen outside of* Black Mirror.

What I'm working on
A story about a fictional planet without plate tectonics.

This column appears monthly. Up next week: James Wong

Editor's pick

How will the virus affect our evolutionary path?

23 May, p 41

From Jim Moore, Coelbren, Powys, UK

While viruses themselves evolve, they have also long driven our physical evolution, and the new coronavirus looks set to influence our social evolution too.

It has highlighted the fragility of social systems and the dangers posed by present lifestyles. Hopefully the "new normal" will increase our chances of being around to learn to live with the virus's successors. The rush to return to business as normal doesn't fill me with hope, however, and neither do the politicians who are hell-bent on pursuing that return.

From Haydn Webb, Duporth, Cornwall, UK

"The truth is rarely pure and never simple." Oscar Wilde seems to have predicted these confusing times of covid-19. Scientists are searching for the means to forge the way ahead through collaborative and verified research. They admit to the gaps in their knowledge.

Yet this doesn't appear to prevent politicians, industrialists and the media from filling in these gaps with abridged interpretations, and making misleading or dangerous decisions aimed at solving financial and social problems. As a consequence, we blunder into the unknown and take a chance.

Greening the seas may not be so easy

16 May, p 36

From Blaise Bullimore , Tiers Cross, Pembrokeshire, UK

Marine algae have undoubtedly brought many benefits to humankind and their cultivation could potentially play a greater role in a more sustainable future, as Michael Marshall describes. Unfortunately, the immense scaling-up of cultivation required to even begin approaching levels that would help prevent climate change will face substantial limitations.

There are reasons why aquaculture operations are concentrated in sheltered and accessible waters. Doing big stuff at sea is difficult, expensive and resource-hungry; it needs offshore and onshore infrastructure, plus continuous maintenance.

Furthermore, the non-trivial task of persuading anything deployed in the open ocean or exposed coastal waters to stay roughly where it was put is always a huge challenge, hence the much higher capital cost of offshore versus onshore wind power.

"All it takes is weighted lines seeded with seaweed floating a few metres below the surface, attached to buoys" is quite an understatement in the context of millions of square kilometres of the high seas. Achieving such large scales of cultivation, for instance of 9 per cent of the oceans, would present stupendous challenges.

Consider dietary advice, preferably well-studied

23 May, p 30

From Michael Allen, Ottawa, Ontario, Canada

The premise that people will overeat carbohydrates and fats in a protein-poor but energy-rich food environment is described in your article as a hypothesis. Fair enough, but the end of the piece says that all you need to do to achieve a healthy, satisfying diet is eat enough protein and top up with wholefoods, mostly plant-based. That sounds like Michael Pollan's "eat food, not too much, mostly plants" advice, with a dollop of protein to take care of the "not too much" part.

To justify such prescriptive advice, the dietary hypothesis put forward by the authors will need long-term, prospective, comparative studies.

It seems Neanderthals were humans too

16 May, p 14

From Guy Inchbald, Upton on Severn, Worcestershire, UK

You say that "before humans arrived, Neanderthals lived in Europe for hundreds of thousands of years. When the two met, they interbred." I beg to differ. Humans interbreeding with non-humans surely makes no biological sense whatsoever. I am forced to conclude that Neanderthals were human and that humans were therefore already there when *Homo sapiens sapiens* arrived.

The editor writes:

Such confusions underline ongoing debates on how to define species (26 January 2019, p 36)

We'll never get to grips with consciousness

2 May, p 40

From Steven King, Crewkerne, Somerset, UK

Regarding the hunt for an understanding of consciousness, I have to quote the late Stuart Sutherland's astute observation and warning in *The International Dictionary of Psychology:* "Consciousness is a fascinating but elusive phenomenon: it is impossible to specify what it is, what it does, or why it evolved. Nothing worth reading has been written about it."

Can we use AI to build a better lie detector?

16 May, p 17

From Dwight Hines, Livermore, Maine, US

It is good and probably useful to detect camouflaged frogs or soldiers with artificial intelligence. But I kept hoping your article would suggest that detecting hidden visual objects might be a good metaphor for detecting camouflaged verbal facts, like the ones that exist in the language of those who lie.

Attempts to build lie detectors based on physiological responses like heart rate, skin conductance and inaudible, high-frequency lip sounds don't pass validity and reliability checks. So let's have some proposals for detecting verbal cognitive inconsistencies using these kind of AI systems. Plenty of verbiage is available in court transcripts for training such technologies.

We're going to need a bigger computer

Letters, 25 April

From Robert Cailliau, Prévessin-Moëns, France

I agree with the string of readers who suggest there are signs that we live in a simulation. Fortunately, Moore's law, which says that computing power tends to double every two years, also applies in some form to the creator or creators of our simulation, so they can keep adding memory and computing power to it. They eventually had to introduce the curvature of Earth. Then, they must have scrambled to put much more detail on the moon when Galileo pointed his telescope at it.

Just imagine adding all those galaxies (and later exoplanets) once we launched Hubble. Unfortunately, they must have had a small problem with delivery of extra memory and so made the Hubble mirror slightly wrong, giving them some breathing space. And not so long ago, they had to make the simulation even more complex with the introduction of the Higgs boson.

Still, it was quite clever of them to set the speed-of-light limit – from which we must be able to deduce the factor of their version of Moore's law.

Want to get in touch?

Send letters to letters@newscientist.com; see terms at newscientist.com/letters

Letters sent to New Scientist, 25 Bedford Street, London WC2E 9ES will be delayed

Welcome to our Signal Boost project. In these difficult times, we are offering charitable organisations the chance to take out a page in *New Scientist*, free of charge, so that they can get their message out to a global audience. Today, a message from **Barnardo's**

Believe in children
Barnardo's

Far from being a "great leveller", the coronavirus crisis highlights society's deep-rooted inequalities

Barnardo's Registered Charity Nos: 216250 and SC037605

Many people have referred to coronavirus as a "great leveller", but at Barnardo's we know this crisis is highlighting deep-rooted inequalities that have been papered over for decades.

While it's true that privilege doesn't mean immunity, the virus shines a spotlight on the stark polarisation in UK society, while disproportionately affecting the most vulnerable.

The illness itself is hitting blue-collar workers and Black, Asian and minority ethnic people hardest. The lockdown and social distancing measures threaten to entrench poverty and inequality for decades to come, risking the future of a whole generation.

While much focus has been on the effects of the virus on older people, children and young people have been largely overlooked.

All children living through COVID-19 are missing out on their education and vital social contact but the most vulnerable children are in the greatest danger, with isolated families cut off from the usual support systems facing growing economic and emotional pressure.

Social divides have never been so pronounced.

Self-isolating is one thing in a large house with a garden and a secure job that can be done from home. It's a very different experience for a single parent whose job is on the line, living in a small flat in a tower block, with no outside space.

Some parents can't help with home learning, and digital poverty – lack of devices or internet access – means many children already at a disadvantage will continue to fall behind at school.

This also means that many children can't access vital support services, whether that's face to face with a support worker or online.

Barnardo's is needed now more than ever before. We acted quickly to adapt our essential services so we can reach vulnerable children and young people online or over the phone to give them the support they need.

But we are facing a perfect storm, with our income decimated overnight while demand for our support skyrockets.

And in the longer term children's mental health, already in crisis, will become a catastrophe, more children will come into the care system and families will fall into poverty.

The shockwaves of COVID-19 will be felt throughout society for years to come – especially by the most vulnerable – and we must be there to pick up the pieces.

Please support our coronavirus crisis appeal today. With our 700 shops closed and our fundraising events cancelled, we need your help more than ever.

- £25 could buy vital phone credits for vulnerable young people, so that they can always call for help or support
- £50 could fund two hours of a care worker's time for 1-2-1 virtual counselling

Donate today: www.barnardos.org.uk/crisis

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The hidden world of fungi

Fungi are perhaps the most enigmatic organisms on the planet, and we are only just beginning to discover how they work, finds **Gege Li**

Book

Entangled Life

Merlin Sheldrake

Bodley Head

YOU may never look at fungi in the same way. This enigmatic community of organisms pulls the strings of life, yet we don't know the half of what fungi get up to. Thankfully, *Entangled Life: How fungi make our worlds, change our minds & shape our futures*, by mycologist and author Merlin Sheldrake, is an eye-opening exploration of this mysterious taxonomic kingdom.

Nothing illustrates this better than when he casts his focus underground. Mycelia – complex, branched networks of fungal cells in soil – form such elaborate connections between plants that they are "as much a part of planthood as leaves, or roots", he writes. This relationship could date back 600 million years, when fungi are thought to have helped plants transition from water to land.

We think fungi transmit brain-like electrical signals through mycelia to communicate with distant parts of themselves. Yet with only two studies looking at this in the past 25 years, writes Sheldrake, this intriguing idea has barely been explored. He says this is the case for most aspects of fungi life and behaviour.

Our rigid definitions are also part of why it is so hard to describe fungi, which, due to the symbiotic relationships they form, often blur the line between themselves and other species.

"To this day, fungi slip around the systems of classification we build for them," writes Sheldrake. "We are unthinkable without them, yet seldom do we think about them."

ARTERRA PICTURE LIBRARY/ALAMY

Conifercone cap fungi (*Baeospora myosura*) growing on a pine cone

Fungi are very efficient: whether they are decomposing matter to release nutrients such as nitrogen into the soil, facilitating communication between plants by forming networks between individuals or bending the minds of organisms by making psychedelic substances like psilocybin, they do everything with aplomb.

> **"Mycelia have proved to be sustainable material for making everything from bricks to artificial skin"**

Of course, we don't really know how they achieve all of this, but that means there is ample opportunity for discovery. As Sheldrake puts it: "There have been so many questions, so few answers – and this feels exciting."

It is hard not to get caught up in Sheldrake's passion and enthusiasm for fungi – amplified by the views and work of various researchers and mycologists he introduces in each chapter – and no less so than when he considers how these organisms can help build the future.

Mycelia have proved to be strong and sustainable material for making everything from bricks to artificial skin, while certain kinds of fungi can help clean up polluted environments by decomposing hazardous waste.

Entangled Life is a journey into an untapped world. It is both a wonderful collection of fungal feats to inspire enthusiasts and future mycologists alike and a personal account of Sheldrake's experiences with these miraculous organisms.

Tackling boredom, an affliction of our times

Book

Out of My Skull

James Danckert and John Eastwood

Harvard University Press

"Drab routine has begun," wrote the Russian cosmonaut Valentin Lebedev, just one week into his seven-month stint aboard the Salyut 7 space station in May 1982. Far from marvelling at the final frontier, Lebedev's diary dwells on the crushing monotony and his sense of isolation. "Everything is down on Earth," he lamented.

There are unmistakable parallels with living through a pandemic. Repetition, constraint and a sense of purposelessness – key factors that lead to boredom – are prominent in life under lockdown. *Out of My Skull: The psychology of boredom* brings together decades of research to make sense of this state, one that is familiar but widely misunderstood.

The authors explain that boredom doesn't affect everybody equally. People who try harder to avoid uncomfortable feelings report feeling bored more often, as do those who struggle with self-regulation. Others experience boredom, but are better at dealing with it quickly and effectively.

Difficulties arise when we try to fight the unpleasant feeling or when we try to distract ourselves with activities that fail to really satisfy, such as mindlessly scrolling social media, say the authors. Seeing ourselves as waiting passively to be entertained undermines our sense of agency, potentially making our problems with boredom chronic. "The solution must come from within us," they write.

Elle Hunt

Chernobyl's strange charm

The site of the world's worst nuclear disaster is attracting an eclectic mix of people, finds **Simon Ings**

Film

Stalking Chernobyl: Exploration after apocalypse

Iara Lee

Free on Vimeo and YouTube

People sit on the Duga radar station inside the Chernobyl exclusion zone

YURIY MARMELADOV. COURTESY OF SEREGA STRANGE

THE film festival circuit is frozen for lockdown, so how are independent film-makers to ply their trade? Cultures of Resistance Films has released this gem to free streaming services. Though it won't get it, the documentary deserves a big splash.

Stalking Chernobyl is a gripping and sensitive exploration of how – little by little, awkwardly and not without controversy and conflict – ordinary people are reclaiming the site of the world's worst nuclear accident.

In 1970, near the Ukraine-Belarus border, ground was broken for the Chernobyl nuclear complex and the neighbouring workers' city of Pripyat. Chernobyl was constructed in a worrying rush, but Pripyat was a labour of love and appreciated by many who lived there. It was a comfortable, well-designed and family-friendly city, full of trees and roses. It had good public transport, a river to wade in, excellent day care and schools, a cracking swimming pool… the list goes on.

On 26 April 1986, an uncontrolled chain reaction tore through Chernobyl's No. 4 reactor. Pripyat was evacuated and a 30-kilometre-radius exclusion zone was established while people fought – and died – to prevent further catastrophe.

The zone is still in place, but it can be visited. I went around four years ago, during the depths of winter. Guides showed us the main sites under snow, fed us in Chernobyl's cavernous canteen and led us through Pripyat, already half-swallowed by surrounding forest. It was lonely and cold. There were wolves.

Since then, the number of visitors to the exclusion zone has doubled each year. That's 40,000 people as clueless as I was, now traipsing about the place.

With them come problems and annoyances. Trespassers build fires at night with local wood, not realising how much radiation they are releasing. Tourists dress up the sites to get better photos. The dolls you find littering an abandoned school are dropped there by tourists, and so are half the books.

> "Ordinary people are showing love and care, each in their own way, to one of the saddest places on the planet"

Stalking Chernobyl's great strength is that it doesn't rush to judgement. Isn't leaving a doll here a little like leaving a wreath? Since when was it wrong to want to explore?

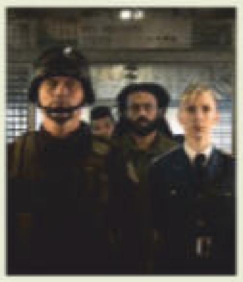
Old hands in the zone complain about the cluelessness of the self-styled "stalkers" who sneak into the site. Yet everyone – even the mayor of Pripyat, whose job it is to keep the zone secure – understands what brings them here.

Meeting communities of trespassers, tourists and guides, we discover that the groups flow into each other. A stalker wants to become a guide. An ex-guide says she will return as a tourist. Several interviewees say the zone is a special place, one that will punish them in some way if they mistreat it.

The film doesn't leave much room to get into the pros and cons of nuclear power. To my mind, though, director Iara Lee has made something more valuable, and certainly more unusual. She has shown how ordinary people – parkour enthusiasts and police officers, base jumpers and festival organisers – are showing love and care, each in their own way, to one of the saddest places on the planet.

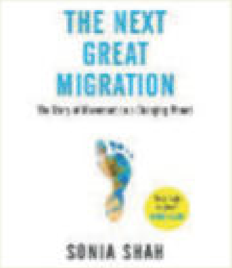
Stalking Chernobyl had me trusting much more than usual in the ability of people to make the best of their society's most terrible mistakes. ■

Don't miss



Watch

Snowpiercer is building nicely by the week. Set on a super-train speeding for survival around a frozen wasteland of a world, the Netflix series is based on a 2013 film of the same name by *Parasite* director Bong Joon-ho.



THE NEXT GREAT MIGRATION

SONIA SHAH

Read

The Next Great Migration explores the history and science of migration, be it by humans, animals, plants or pathogens. Sonia Shah explores the history and science of migration, and reveals how species are escaping warming seas and desiccated lands in a mass exodus.

Play

Acute Art is an app that has partnered with artists Olafur Eliasson and KAWS to offer a series of small pieces and studio experiments rendered in augmented reality. Download it now to start your collection.

T & B: JUSTINA MINTZ/TNT; KAWS & ACUTE ART

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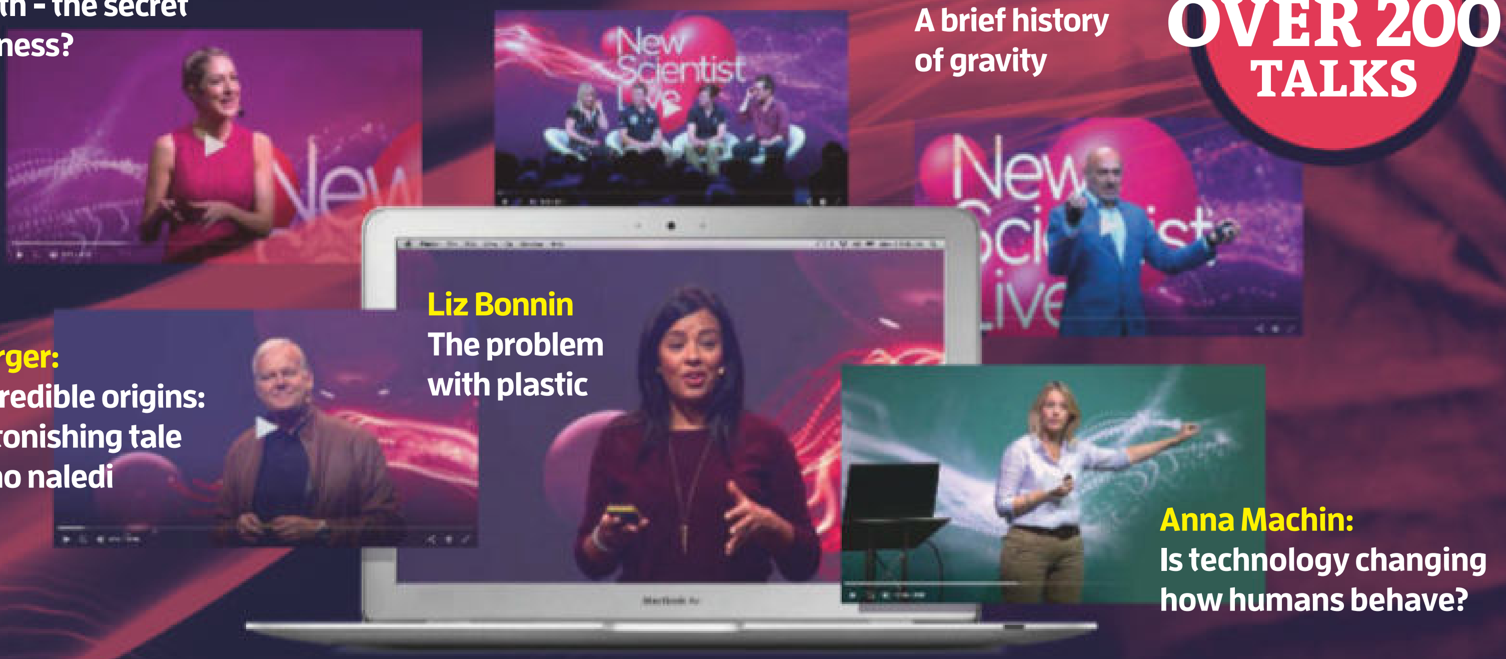

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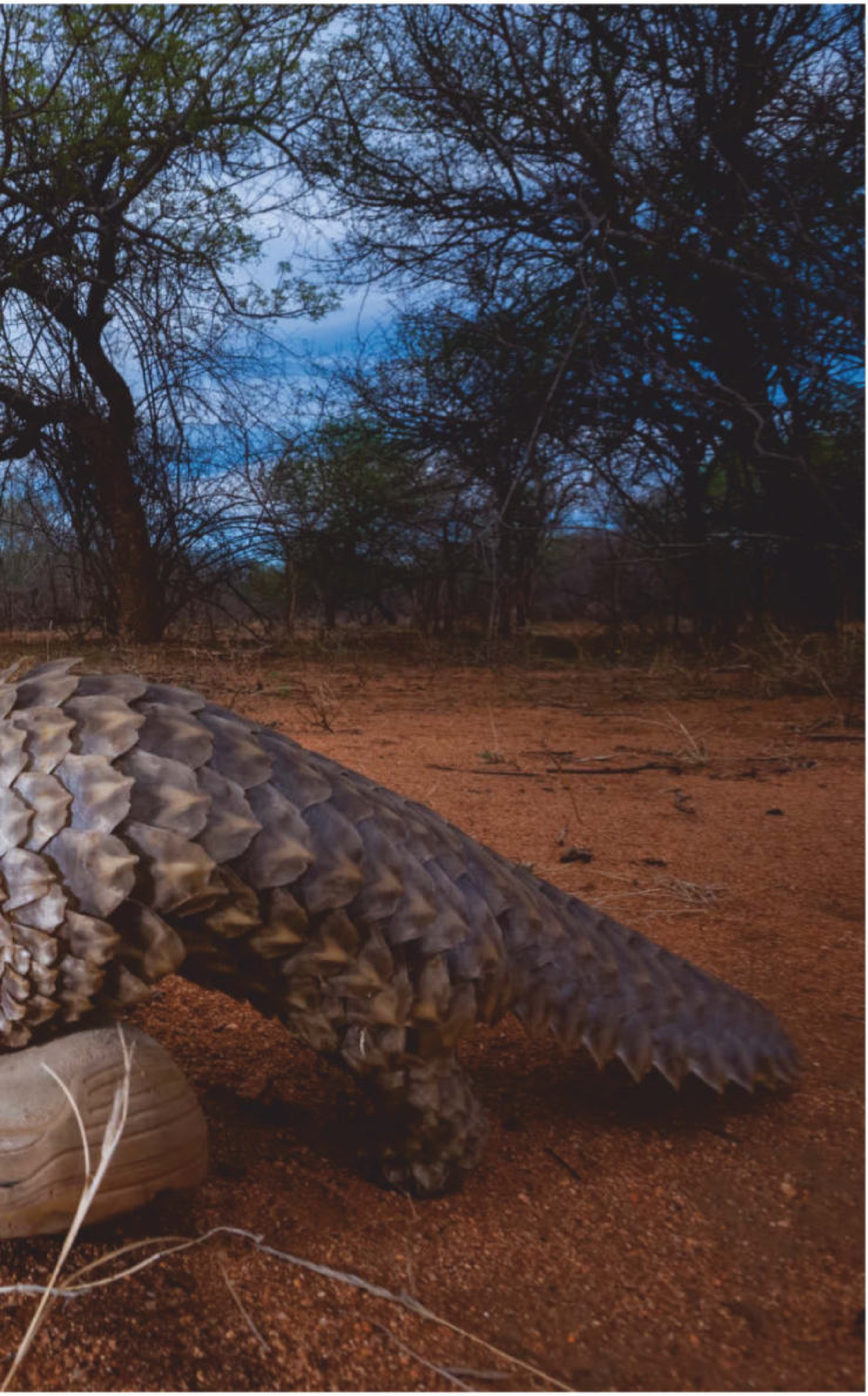

Under threat

Photographer Neil Aldridge
Agency naturepl.com

THIS curious creature is a pangolin, the only mammal that is covered in protective scales.

This signature feature is why pangolins, which are native to Asia and sub-Saharan Africa, are frequently illegally trafficked, traded and hunted: their scales are used in traditional medicine in China and parts of Africa. There is no scientific evidence that pangolin scales, which are made of keratin – the same substance as human fingernails – have any medicinal properties. Pangolins are also hunted for their meat, which is considered a delicacy in some countries.

The pressure on pangolins is compounded by habitat loss and their slow reproductive rate: they give birth to just one pup each year.

In 2016, signatories to CITES, the international treaty on the wildlife trade, voted to ban the trade in pangolins, yet poaching and trafficking persist. All eight species of pangolin are now threatened with extinction.

This image of Aura, an adult female pangolin that was rescued in a sting operation, is part of a series by photographer Neil Aldridge called Protecting Pangolins. The photos detail efforts by conservationists at an animal rehabilitation centre near Hoedspruit, South Africa, to halt the pangolin's decline before they go extinct.

Gege Li

Have we got the universe right?

Nobel prizewinner **Jim Peebles** contributed more than most to our standard model of cosmology – but it's unlikely to be the final answer, he says

IF SUCCESS is measured in Nobel prizes, we have got something right with our standard model of cosmology. In the past two decades, three prizes have been awarded for advances in the study of the large-scale nature of the universe. Our picture of a cosmos that some 13.8 billion years ago was in a hot, dense state and has been expanding and cooling ever since is in close agreement with a considerable variety of observations.

But you can argue it the other way, too. Our cosmology assumes that most matter comes in a "dark" form that hasn't yet been detected. It relies on Albert Einstein's cosmological constant, a seemingly arbitrary addition, to explain why the universe's expansion is apparently speeding up. Even if you are prepared to overlook these difficulties, there is the unsolved question of what the universe was doing before it was expanding.

A sceptic might view complications such as dark matter and dark energy, the current incarnation of the cosmological constant, as today's equivalent of the Ptolemaic epicycles, the convoluted tweaks made to the model of the planets' motions to maintain the fiction that they were all revolving around Earth.

I have more skin in this game than most: I introduced the mystery elements of dark matter and dark energy into our standard cosmology. So is the model I helped construct right; is our cosmology a true reflection of reality? In what follows, I will strongly argue yes – but only as far as that goes.

Fossil footprints

The evidence for a universe that began in a "big bang" is serious. The chief witness is a close-to-uniform sea of microwave radiation of wavelengths from millimetres to centimetres that fills all of space. As a postdoc with my adviser and mentor Bob Dicke more than half a century ago, I explored the idea that the early universe may have been hot, and left behind a background of such long-wavelength radiation as it expanded and cooled. Shortly after, in 1964, this "cosmic microwave background" was accidentally discovered by Arno Penzias and Robert Wilson as the by-product of experiments testing telecommunications equipment.

In 2006, John Mather was awarded a share of the physics Nobel prize for his leadership in showing, with measurements from the Cosmic Background Explorer satellite (COBE), that the spectrum of the cosmic microwave background radiation – its energy density at different wavelengths – is that of radiation that has entered thermal equilibrium. This process will occur only if the density of the surrounding matter is sufficient to trap the radiation, forcing it to relax to thermal equilibrium. This isn't the case in the present-day universe, through which microwave radiation can travel freely. I countthe spectrum of the cosmic microwave background, preserved as the universe expanded and cooled, as tangible evidence that our universe really evolved from a different state, just as dinosaur footprints show us that massive creatures once roamed Earth.

The other half of the 2006 Nobel prize went to George Smoot, who led the demonstration that the cosmic microwave background isn't completely smooth. The tiny variations of its intensity across the sky, which have been mapped out in detail in later measurements, are consistent with what would be expected in an expanding big bang universe with

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those two additional, hypothetical components: dark matter and dark energy.

When I added the first of these into the mix in the early 1980s, my motivation came in part from early measurements of the cosmic microwave background, which were already good enough to show us that the radiation is quite smooth. Yet we could see that matter came in great clumps: galaxies and groups and clusters of galaxies. This led to talk of a crisis in cosmology. How could matter have been pulled together in great concentrations without pulling the radiation with it?

My proposal was that most matter isn't the "baryonic" matter of the kind you and I and stars and planets are made of. The non-baryonic dark matter I had in mind wouldn't interact with normal baryonic matter, except through gravity, or with radiation. As it clumped under the influence of gravity, it would slip through the radiation of the cosmic microwave background, leaving it largely undisturbed.

> **"You have to be careful not to build a cosmological just-so story"**

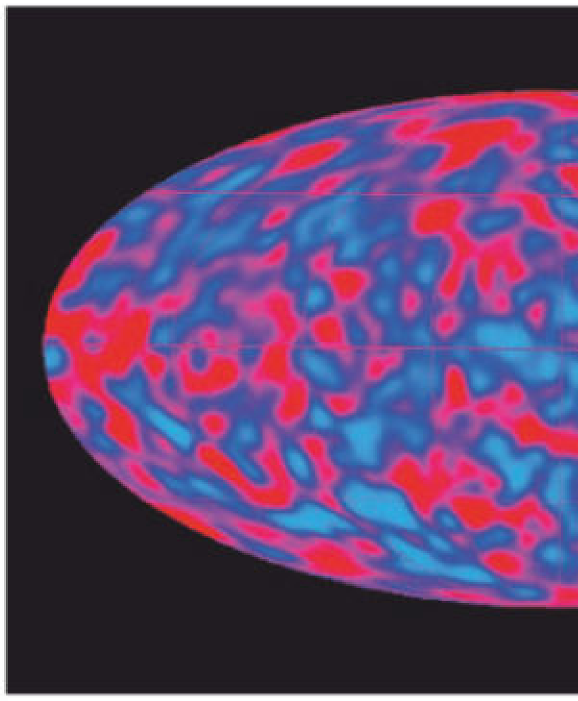
You have to be careful with this sort of adjustment of a hypothesis to fit what is wanted, lest you build a "how the leopard got its spots" just-so story. But I had two other hints to go on. First, there was astronomical evidence that most of the mass on the outskirts of galaxies isn't very luminous. If the visible matter were all that existed, the galaxies would fly apart, based on the speed at which they are rotating.

The second hint came from particle physics. Back then, there were two confirmed families of the fundamental particles known as leptons: the electron and its neutrino, and the muon and its neutrino. There was also growing evidence of a third family, made up of what became known as the tau and its neutrino. So why not a fourth?

The attraction of this idea was that if this fourth neutrino were heavy, with a mass about three times that of a proton, a sea of them left from the hot early universe would provide about the matter density required for the universe to be expanding at "escape speed". This is the name given to the rate of expansion at which the gravity pulling together the universe's matter is just enough to slow expansion down, but never quite stop it or reverse it back to a "big crunch", by analogy to the speed a rocket must attain so it can just escape Earth's gravity, rather than fall back to the ground.

At the time, it looked like the average matter density of the universe was smaller than this critical number, by enough that the expansion rate was around twice escape speed. That would point to a curious coincidence: that we are currently observing the universe just around the time when the expansion rate has beaten gravity and started to expand freely. This problem would be solved if the universe contained just the right matter density. In that case, whenever in the history of the universe we happened to flourish and take an interest in its expansion, it would always be growing at escape speed. The thought is comforting somehow, and many argued for it, including me, but it is wrong.

I think for the particle physicists who were theorising a fourth, massive type of neutrino, it was just an interesting idea. They may have been vaguely aware of the escape speed argument, but they knew little of the evidence for invisible extra mass around galaxies. Putting the two hints together with the need to account for the quite smooth sea of thermal radiation resulted in the cold dark matter model. The "cold" refers to the fact that the particles making up the dark matter would be moving slowly relative to the general expansion of the universe, an important property in the model to ensure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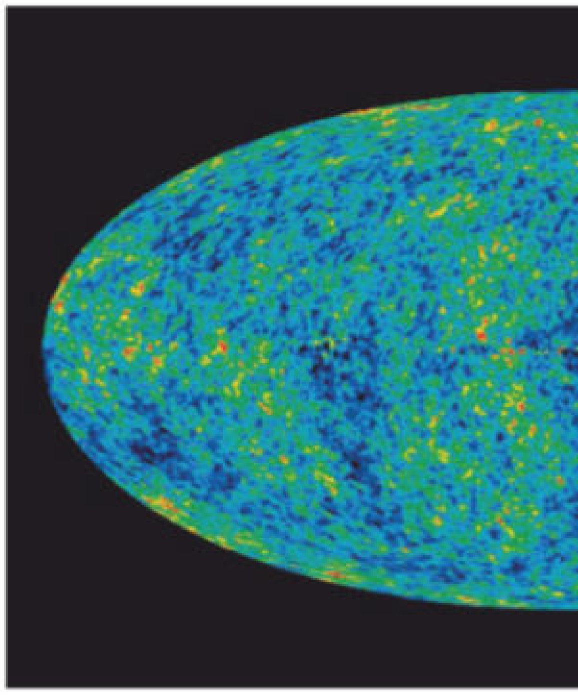
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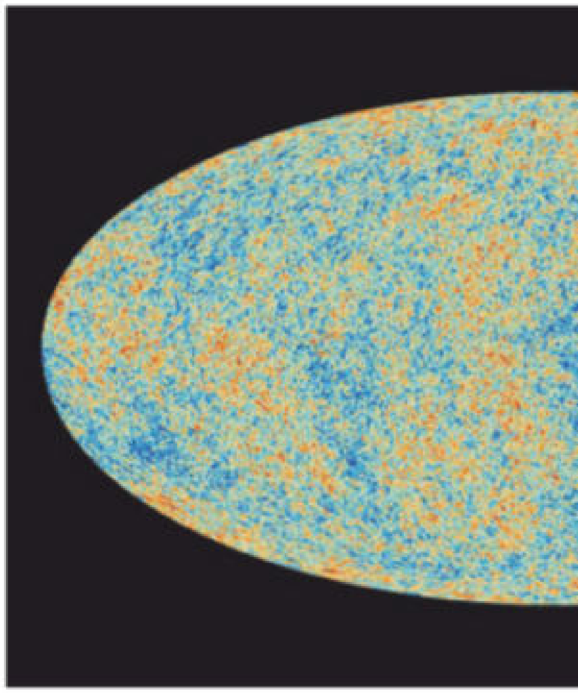
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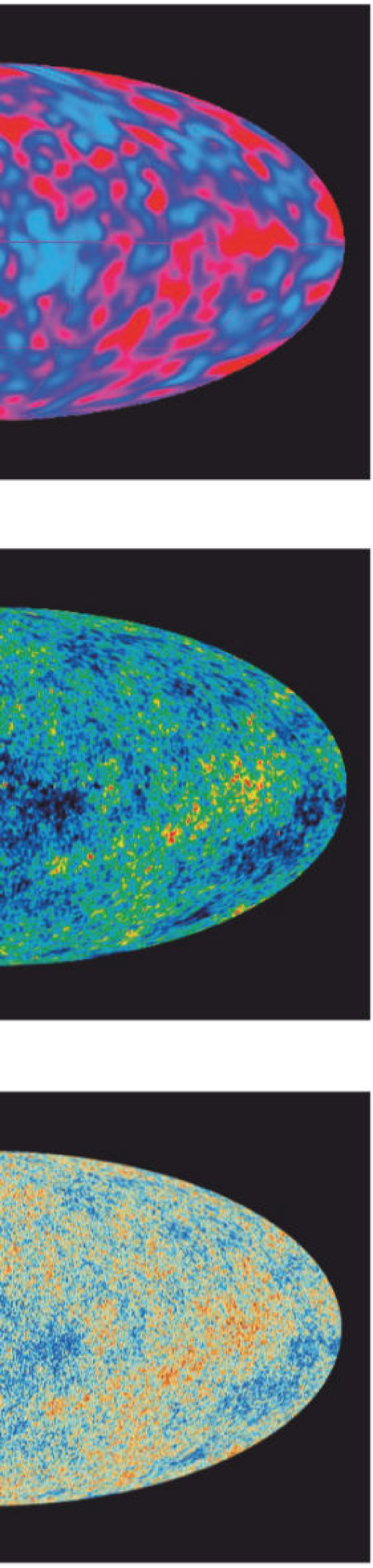

Maps of the big bang's microwave afterglow from three generations of probes. Top to bottom: COBE (operational 1989-1993), WMAP (2001-2010) and Planck (2009-2013)

the formation of galaxies and clusters of galaxies of the sort we observed.

I offered just one prediction with this proposal when I made it in 1982: that the cosmic microwave background temperature would vary in different parts of the sky by about four parts in a million. This agrees with the measurement accomplished some two decades later by COBE. The prediction came about partly through educated guesswork, and partly because I had spent a lot of time measuring the large-scale distribution of matter across the universe, so had a guide as to its expected gravitational effect on the radiation.

Meanwhile, I had also been working on measures of the universe's average matter density. Such efforts had left me pretty sure that this density is small enough that the expansion of the universe would actually be faster than escape speed, fourth neutrino or no fourth neutrino. This wasn't welcome: expansion at escape speed seemed so right. But to me, it seemed to call for the reintroduction of a cosmological constant into the model.

> **"The tiny value for Einstein's constant is preposterous – but it works"**

Einstein had introduced this constant back in 1917 with the intention of maintaining a static universe that was neither expanding nor contracting, a situation he seemed to have taken for granted. He came to dislike it when observations in the following decade proved the static model wrong. Particle physicists today really dislike it because its natural value, the quantum vacuum energy density, is ridiculously large compared with what is required to fit the evidence.

When, in 1984, I first argued for the cosmological constant's reintroduction, at a tiny value that looks preposterous but works, I remember a capable younger physicist saying to me something along the lines of the quote from *Alice's Adventures in Wonderland*: "He only does it to annoy, because he knows it teases." I knew it was annoying, but I was serious. Vindication came almost two decades later, when results from three great experimental programmes in cosmology arrived during a half-decade stretch around the year 2000.

The first set of results came from a thoroughly cross-checked array of feasible, though difficult, methods to measure the average cosmic matter density, which by 2000 had produced a good case that the universe is indeed expanding faster than escape speed. The coincidence argument I mentioned meant that many continued to feel this must be an error, but the measurements certainly influenced me, and I think others.

The second confirmation came from measurements of the universe's changing rate of expansion by detection of the light from supernovae exploding in distant galaxies. Far-off galaxies are seen as they were in the past because of the time light takes to travel to us, and the Doppler shift also changes the wavelength of that light according to the galaxy's motion relative to us. By 2000, the data from supernovae in galaxies at different distances pretty convincingly showed that the rate of expansion is not only greater than escape speed, but is also growing over time. The measurement led to the rebranding of the cosmological constant as dark energy, and later to the 2011 Nobel prize being awarded jointly to three members of two competing teams: Saul Perlmutter, Adam Riess and Brian Schmidt.

The third vindication for the cosmological constant hypothesis came from the precise measurement of the variation in the temperature and polarisation of the cosmic microwave background radiation across

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CHRIS GUNN/NASA

The James Webb Space Telescope, due to launch in 2021, will be the next big probe of the cosmos. A full-scale model (left) is on display in Austin, Texas

NASA/ESA/NRAO/AUI/NSF AND G. DUBNER

the sky, which yielded a tight constraint on the effects of dark energy and dark matter.

Why did these three great efforts reach the required precision to make these measurements at close to the same time? I suppose it was, in part, simple coincidence. But all three relied on technological advances in the detection of radiation, from X-rays to optical light to radio waves, and great improvements in computing power and storage to deal with the vast amount of data they produced. The technology was by and large developed for other purposes – it is what gave us people walking about looking at their smartphones instead of where they are going – and was adapted by inventive astronomers for cosmological tests.

The consistent case from these three different ways of probing the universe convinced most cosmologists that the model with dark matter and dark energy is almost certainly on the right track. Since then, measurements have tightened the evidence. But I had assembled this cosmology out of the simplest assumptions I thought I could get away with. I can't have consistently guessed right. Indeed, precise measurements have shown that the initial conditions I assumed – for instance in the detail of how matter warps space-time – were a little out.

Surely there are more adjustments to come. An example may be the current 10 per cent discrepancy in the rate of the universe's expansion derived in two different ways. One, like the supernova measurements honoured by the Nobel committee in 2011, uses measurements of the distances to galaxies and their rates of motion away from us derived from Doppler shifts. The other comes from adjusting the parameters of the cosmological model to fit the precise measurements of how the cosmic microwave background varies across the sky. If the model is right, the two measurements ought to give the same answer. Maybe the difference is down to a subtle systematic error, which wouldn't be surprising for these difficult measurements. Or maybe it is evidence of something new. I haven't joined the search for what that something new may be, but I will be fascinated to see what people come up with.

> “Despite all our searching, dark matter is still a hypothetical substance”

There are other cross-checks we can do to test the standard cosmological model, for example on the abundance of helium. We have three ways to estimate this. First, the measured relative abundances of hydrogen and deuterium allow us to predict how much helium formed in thermonuclear reactions in the hot early stages of the universe's expansion, when the cosmic microwave background had a temperature a billion times its current level of 3 kelvin above absolute zero. This prediction assumes our cosmological model is a good approximation all the way back to that very early time, of course.

Second, we can estimate the helium abundance from the distributions of matter and radiation when the background temperature of the universe was a thousand times its present value, hot enough that baryonic matter was ionised and the resulting

Data and images from the Hubble Space Telescope, such as this shot of the Crab Nebula, have guided cosmological discoveries since its launch in 1990

RICHARD SODEN

PROFILE

Jim Peebles is Albert Einstein professor of science, emeritus, at Princeton University. He was awarded one half of the 2019 Nobel prize in physics "for contributions to our understanding of the evolution of the universe and Earth's place in the cosmos". His book *Cosmology's Century* is out this month.

plasma tightly bound to the radiation. Helium is denser than hydrogen, so its presence affects the way that the plasma moves in response to the pressure of surrounding radiation.

Third, astronomers can measure how much helium there is in nearby stars and plasma. All three methods provide consistent results so far, which is really impressive. Surely they will continue to do so as the measurements improve in accuracy? Maybe, but wouldn't it be exciting if they didn't?

Yet even if continued agreement further bolsters our confidence in the accuracy of the model, the central mysteries of dark matter and dark energy remain. Cold dark matter is still a hypothetical substance, despite laboratory experiments since the 1980s of ever-increasing sensitivity looking for its occasional predicted interactions with normal matter. Detection would be really exciting. But it is possible that dark matter is completely decoupled from the baryonic matter and radiation we are familiar with, never to be detected, apart from through its gravitational effect holding galaxies together that we already know of.

And what should we make of dark energy? A great deal of work is now focused on discovering whether its value changes as the universe expands. That would mean it isn't a cosmological constant with a really odd value, but rather that it plays a role in the universe's dynamics. Working out that role would be both a great challenge and a great opportunity.

Then there are those other great challenges for modern cosmology, such as explaining precisely what happened at the big bang. The elegant idea of ballooning cosmic inflation smooths out some otherwise inexplicable wrinkles in that story, and suggests the big bang may have spawned a multiverse of universes beyond our own. But again, that idea lacks evidence.

Messy and incomplete

We haven't been issued a guarantee that we can make sense of the physical world around us, or detect things such as dark matter. But lest there be doubt about how well physics has been doing so far, consider how successfully scientists and engineers can command the behaviour of electrons, atoms and molecules, as well as electric and magnetic fields, in cellphones. All of this has been done based on incomplete approximations.

The theory of electric and magnetic fields that James Clerk Maxwell put together in the 19th century is still used in designing cellphones, electric power grids and so much more. But Maxwell's theory is only a limiting case of quantum electrodynamics. That larger theory in turn emerges as a consequence of a broken symmetry in the standard model of particle physics, which is in turn a messy confusion of seemingly arbitrary parameters. Surely there is something better, maybe some variety of superstring theory to be discovered? And after that?

My point is that all of physics is incomplete. I certainly don't mean wrong, I mean that it can all be improved. Maybe there is a final theory of physics, or maybe it is approximations all the way down. And so it is with cosmology.

When I started my cosmological research all those decades ago, I was uneasy at first because the subject then really was a kludge of ideas supported by pathetically little evidence. The evidence is now vastly more abundant and instructive, yet there, still, is the kludge of those hypothetical components. I don't expect our current model will prove to be false. But I do expect we can do better – allowing future cosmologists to garner their continued share of Nobel prizes. ▮

Accounting for nature

Gretchen Daily's efforts to encourage people to value nature have taken her around the world, from Latin America and the Caribbean to China, and from government offices and boardrooms to tropical rainforests. Adam Vaughan caught up with her

ROCIO MONTOYA

IF YOU have ever heard of "natural capital" or "ecosystem services", then it is probably because of Gretchen Daily. The Stanford University biologist pioneered these concepts, which aim to evaluate nature and what it provides us with, and factor these values into economic decision-making.

Many countries have taken them on board, including the UK government, which has a committee to advise on natural capital. Nevertheless, the idea is contentious. Proponents argue that ignoring nature's value when planning new homes, roads and infrastructure hasn't served wildlife and habitats well. Critics say putting a price on nature will make our degradation of it worse.

In 2006, Daily helped to launch an international partnership, the Natural Capital Project, bringing together academic and conservation groups to further this agenda. She has also developed a metric to rival GDP, called Gross Ecosystem Product (GEP), which could help countries better value nature.

Adam Vaughan: Why do you think natural capital is so divisive as a concept?

Gretchen Daily: If one has been fortunate enough to get to know nature, then nature is infinitely valuable. And it's beyond crass to put a price tag on nature, to quantify even the value of some dimension of nature. It's kind of like putting a price tag on human life. And I share that perspective. But most people don't know nature. So many kids are growing up in urban contexts where they never even get their hands in soil, or climb a tree, or see the stars in the sky at night. And it's a fantasy to think otherwise. In most arenas of the world, nature scores an absolute zero.

We're not about putting a price tag on nature. That's the shorthand that's often used. We are all about this deeper transformation: it's much more about engaging people and enabling people to be part of the solution.

Over the past century, we have been undergoing the great degradation of nature. If we are going to take this beautiful blue planet to a place that by the end of this century is remotely liveable for our descendants, we have to bring nature into the core of decision-making and into those cost-benefit arenas – and change those arenas. But it's not going to happen overnight. In the short term, it's about driving together the economic decision-making with valuing nature. Over the long term, I hope very much that there's a deeper cultural shift.

The Natural Capital Project was set up to help make this happen. How is it going?

There's a widespread recognition that we need to include the values of nature in decision-making, in a very systematic kind of way. The way we have operated has been through partnerships with governments, banks, businesses, communities and other groups. We aim to understand why decisions are made the way they are today, and how we can then go about changing them.

One of our biggest successes has been China. It has recognised how devastating the 20th-century industrial revolution growth model has been. It was pursued for good reasons, lifting people out of

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poverty. Yet it went way too far. The price tag is really devastating – the poisoned water, the poisoned air, the poisoned land. Now, the Chinese leadership has asked three questions. The first is where and how much nature should we protect: it is pursuing the idea of an ecological civilisation. Second is how can we harmonise people in nature and have jobs. The third question is how can we track our performance.

Given China's emphasis on economic growth, is it really taking rival metrics to GDP seriously?
We know GDP is China's main metric for tracking performance, and it is used in promoting or demoting government officials. The merit system is very GDP-growth oriented. Its number one use of GEP accounting is to illuminate for society nature's values – all the interconnections. In the GEP accounting, you can see exactly where the values are coming from, at what levels, how they change through time and which landholders are stewards of nature.

China has this party school that all officials get trained at. One of the school curricula now focuses on natural capital, and it has become a major programme. I've met with the leader of the programme. It's definitely being taken seriously.

China has a clear motivation to clean up its own environment, but is there any hope it will extend these standards internationally, for example in the giant construction projects in its Belt and Road Initiative?
China is coming out of the century of shame, of the time of Opium wars and other foreign involvement. [The period between 1839 to 1949 is sometimes called the century of humiliation.] It's now wanting to re-emerge as a new civilisation. There is this matter of building a new identity and I think it's an open question how much that will be around the ecological civilisation and China's position in the world.

The countries in which it is investing are desperate for investment. In the best form, China would deploy the same approaches that it is now requiring domestically in its overseas investments. China will always say: "Well, we don't meddle in the national affairs of other countries and their policies." But if we are going to get to an ecological civilisation globally, China has to dictate a standard. It could go either way.

> "We are expected in our lifetimes to lose at least half of the types of life forms on the planet"

CHARLES J. KATZ, JR

Given that the world has missed the majority of the UN biodiversity targets it set a decade ago for 2020, how would you say international efforts to stem our destruction of nature are doing?
I feel we are really at an inflection point, so my heart is in my throat. We are expected in our lifetimes to lose at least half of the different types of life forms – the different plants and animals – that inhabit the planet. But on the bright side, there are examples from many countries of tremendous progress. For example, in Ecuador, rights for nature are written into the constitution. Curridabat in Costa Rica has made pollinators citizens of the town. I feel we see a huge surge of interest on the part of countries worldwide to take up the natural capital approach because it promises to open a pathway of both green and inclusive development.

Will the covid-19 pandemic change our perceptions about nature?
Even with the uncertainty as to the virus's exact transmission pathway and point of origin, the lessons are very clear: there is tremendous risk in consuming wildlife, and in these wet markets. We are all deeply interconnected – people and wildlife. We need a much deeper transformation of how we think about wildlife and whether we trade in wildlife, and also in the food system more broadly. With so many people on the planet, we need to really rethink how we produce food, and that's in every country.

CHARLES J. KATZ, JR

Gretchen Daily has worked with people in Lishui, China, to make tea production more socially responsible

Realising the value of natural capital inspired locals to save this kapok tree in Costa Rica from deforestation

You told me that natural capital shows a way to "build back better" after the pandemic. Is it fanciful to hope that governments will prioritise valuing nature as they rush for economic recovery?
I do think there's a huge risk that it will sound like a green diabolical plan that's insensitive to the suffering of so many millions. Pandemics have always been and always will be part of the human experience.

But the blessing is that this one has caused us to pause, and that we have come far enough in driving this transformation [of governments and other institutions valuing nature] in a very quiet and almost unknown way. It is under way in a powerful enough set of institutions, in a diversity of cultures.

If it were only China, we wouldn't be able to get anywhere. It's the fact that it's all across Latin America and it's coming up in many other countries: other parts of Asia, parts of Europe. It's embedded enough. We have the opportunity of a lifetime now, because people can see that with the stroke of a pen, we can change everything.

Even in the US, where president Donald Trump has rolled back many protections for wildlife and ecosystems?
The changes have been under way for a long time and predate Trump and this administration. They have long-term implications for sure. And it will be hard to get the environment back onto the more conservative or right wing agenda. There's a complete disregard for science: we could see that with Mike Pence visiting a hospital and not wearing a mask. If we manage to get a different administration in this year, at November's election, then there's a chance to build back better. If we don't, then there's deep concern.

Politics clearly matters when it comes to preserving nature, but it is unusual for an academic scientist to be so engaged with governments and other stakeholders. What factors have shaped your world view and approach to your work?
I was born in Washington DC, and lived between the US and Germany. We travelled a lot. In Europe as a teenager, I saw all the protests over acid rain, corporate capitalism and America – all these movements that intermingled together with the environment movement. And that's what got me into this area of science.

I thought way back then that scientists could make a difference, and that science was the answer. I definitely see science as part of the answer now, but I have been humbled each step of the way as to how there are so many other essential elements and ingredients to driving the transformation that we need.

I understand that biologist and population expert Paul Ehrlich was an influence, too. You first met him when you mistakenly attended his class thinking he was the German Nobel-winning immunologist of the same name. What did you learn from him?
I ended up becoming interdisciplinary in ways that I learned through Paul. He has developed expertise in many different fields. He also let me realise that to become an effective scientist, I would have to connect with all types of people. And he gave me confidence that I didn't have at the beginning to do stuff that others might not have been doing.

Despite all this, you still find time to do fieldwork. Is there anywhere in the world particularly special to you?
Costa Rica. I feel it awakens something that is probably in all of us. Being out in a place where the dawn chorus is so loud you cannot possibly sleep through it. It's impossible to sleep in, because there are so many different insects, frogs, birds and mammals. They just go nuts in the morning and I absolutely love being in the midst of all that. ∎

Adam Vaughan is chief reporter at *New Scientist*. He also writes the Fix the Planet newsletter. Sign up at newscientist.com/fix

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Once bitten

Can a single tick bite really ruin your health for good? **Chelsea Whyte** investigates

BARELY a summer day went by that I didn't hear someone talking about Lyme disease. In the four years I lived on Long Island in New York, checking for ticks became second nature. After a walk in the woods. After a stroll in the marshy grasses by the beach. After a backyard barbecue.

I remember the first one I found on my clothing: a lone star tick, its distinctive white dot almost shining up at me from the crook of my elbow. I panicked until I found out that lone stars don't transmit Lyme disease.

The first time I found the kind of tick that does spread the disease burrowing into my leg, I retched, then rushed to the doctor; the second time, I calmly went to the clinic to have it removed and get tested. In time, panic gave way to low-level, background worry.

Maybe I was right to be alarmed. Lyme disease is on the rise around the world. This bacterial infection spread by tick bites can lead to joint pain, fatigue, neurological damage and even temporary facial paralysis. If caught early, it is treatable – in most cases. But some people report symptoms that never go away, even after treatment.

"For some people, Lyme disease symptoms never go away"

This condition is commonly known as chronic Lyme disease. Yet we still don't know whether Lyme disease, which is maddeningly difficult to diagnose, is the true culprit. What is clear is that a growing group of people are in pain and distress. Helping them means finding an answer to a surprisingly difficult question: does chronic Lyme disease exist? Can a single tick bite really undermine your health for the rest of your life?

It is undisputed that Lyme disease is becoming more common. In the US, around 15,000 cases were reported each year in the late 1990s. Today, it is about 30,000 cases, although recent estimates from the Centers for Disease Control and Prevention suggest that 10 times as many people get the infection. In the UK, there are an estimated 2000 to 3000 new cases every year, but a recent analysis suggests the real figure may be closer to 8000. Elsewhere in Europe, Lyme disease cases have been steadily rising for more than 30 years, and the World Health Organization estimates that now at least 65,000 people in the region get the disease annually.

Lyme disease is nothing new. A bacterium that causes it, *Borrelia burgdorferi*, can now be found throughout North America as well as in parts of Europe and Asia. It was thought to have originated in North America, until a 2008 study of the bacterium's genes placed its origins in Europe. But by around 15,000 years ago – long before humans crossed the Bering Strait – it was present in North America, quietly colonising birds, small rodents and deer.

When humans arrived, we slowly reduced the number of predators that kept these host animals' numbers in check. As their numbers grew, so too did the number of ticks that transmit *B. burgdorferi*.

We didn't know about this particular danger until 1977, when Lyme disease was first identified. It was named after a town ›

in Connecticut where a cluster of children developed what seemed to be juvenile arthritis after first getting a mysterious bullseye rash. This "Lyme arthritis" was eventually renamed Lyme disease, and a few years later entomologist Willy Burgdorfer pinned the blame on *B. burgdorferi*, a spirochete bacterium, so-called because it is shaped like a corkscrew. It causes the vast majority of Lyme disease cases in the US. In Europe, *B. burgdorferi* is still present, but two other species, *Borrelia afzelii* and *B. garinii,* cause most cases of Lyme disease.

The precise mechanisms behind Lyme symptoms aren't well understood, but we do know that when a tick carrying a type of *Borrelia* bites you, the bacteria replicate in the tick's gut and pass through its salivary glands into your bloodstream, a process that can take up to 48 hours. That may sound like a long time not to notice a tick hanging off your body, but most Lyme disease infections are brought on by a bite from a nymph, an immature tick that can be as small as 2 millimetres wide.

Some research indicates that the bacteria then activate enzymes that can cause collagen fibres – like those in tendons or ligaments – to break down, resulting in weakness or arthritis-like symptoms. Pain and tingling, as well as more severe neurological damage, may be caused by the inflammation of tissues or nerves after direct contact with the bacteria, or it could be a result of immune responses to the bacteria.

Detecting *B. burgdorferi* is difficult. It replicates slowly but moves quickly out of the blood and into body tissues, making direct blood tests less effective. Even when we can find the bacteria, they are nearly impossible to grow in culture, meaning we need highly sensitive tests to identify them in order to confirm an infection. We simply don't have those, says John Aucott at Johns Hopkins University in Maryland.

Instead, we keep an eye out for a telltale bullseye rash, or erythema migrans, that 70 to 80 per cent of people get. It usually crops up a few days to a month after a tick bite and can linger for weeks. Spotting this distinctive rash isn't a foolproof diagnostic method, however. It can be easy to miss – either because it is in a hard-to-see place on your body or has faded before you notice.

EYE OF SCIENCE/SCIENCE PHOTO LIBRARY

Ticks transmit Lyme disease by passing on *Borrelia* bacteria when they bite

Tick check

Simple precautions can go a long way to reducing your risk of contracting Lyme disease. In places where Lyme disease is common, the US Centers for Disease Control and Prevention offers this advice for people who spend time outdoors, particularly in grassy or woody areas:

- **WEAR INSECT REPELLENT**
- **CHECK FOR TICKS DAILY**
- **SHOWER SOON AFTER BEING OUTDOORS**
- **CALL YOUR DOCTOR IF YOU GET A FEVER OR NOTICE A BULLS-EYE RASH**

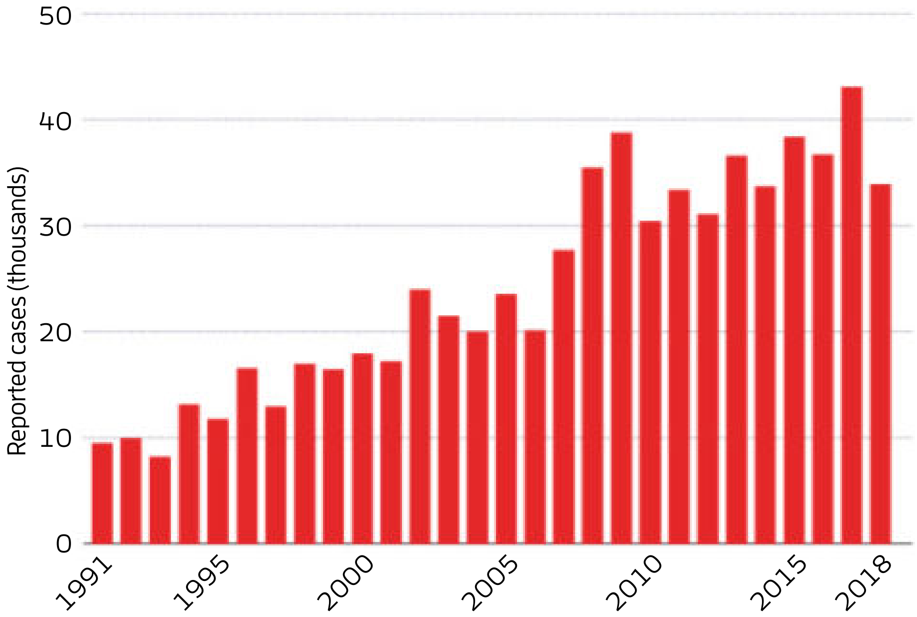
For more detailed guidance on prevention, go to cdc.gov/features/lymedisease

It also may not also be visible under hair or on darker skin. A recent study led by researchers at the University of Maryland found that African Americans were less likely to notice the rash than white people, and were also more likely to have arthritis after contracting Lyme disease. One reason may be that if people don't see the rash, they are less likely to receive treatment before long-term symptoms set in.

If a rash has been spotted or you suspect Lyme infection, there are several kinds of tests that look for antibodies that the immune system produces to fight the infection. It can take several weeks for the body to produce enough antibodies to show up on these tests. These antibodies can also have similar proteins to those deployed to fight other invaders, leading to false positive results. And antibodies to Lyme disease can linger in the body after an infection has cleared, so these tests cannot determine whether someone has a current infection. All these issues mean that a combination

Not out of the woods

The number of reported cases of Lyme disease in the US has increased steadily since 1991 – and health authorities believe 10 times as many cases may go unreported



SOURCE: US CENTERS FOR DISEASE CONTROL AND PREVENTION

of the two most common tests are only accurate about 40 per cent of the time.

For doctors, it can be a very frustrating situation, especially when it comes to assessing chronic symptoms. Lyme disease should be simple to treat because we have antibiotics that fight the bacteria that cause it. But because many people don't realise they are infected and tests for Lyme disease are so unreliable, it can be nearly impossible to determine whether someone who seems to have chronic Lyme disease was actually infected with Lyme initially or has another condition altogether.

"A lot of the work we do on a day-to-day basis as a clinician is detective work. And when you cannot find a clear biological marker that justifies what disease the patient has, it's extremely frustrating. But we often cannot find any evidence that bacteria are still there," says Marcelo Campos, a primary care physician in Massachusetts and a lecturer at Harvard Medical School.

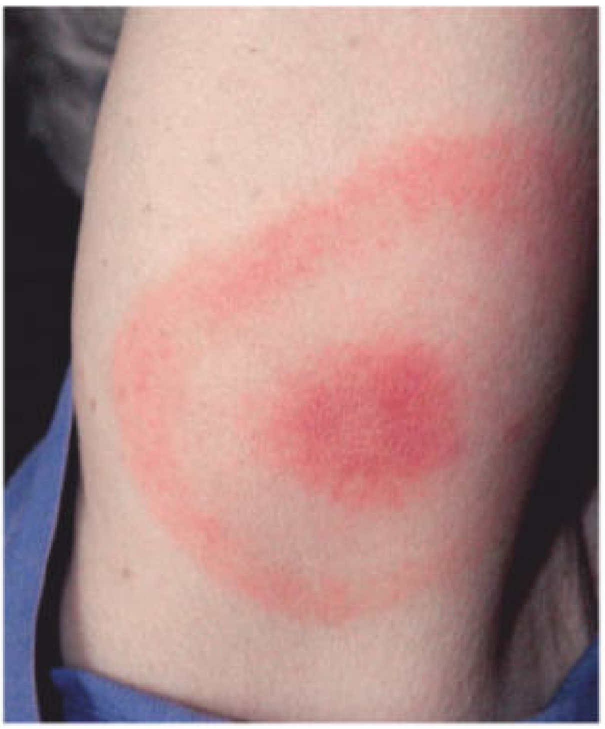
That fact, and the nebulous definition of chronic Lyme disease, has led some doctors to question whether *B. burgdorferi* is really to blame. This scepticism has driven a bitter conflict between patient groups fighting for recognition of chronic Lyme disease and a medical establishment baffled by how to diagnose, let alone treat, something with no discernible cause.

This conflict is worsened by the tension over misuse of antibiotics: some activist groups, such as the International Lyme and Associated Diseases Society, advocate long-term antibiotic treatment for people with chronic Lyme disease. This is despite several clinical trials demonstrating that the approach works no better than placebo and comes with significant risks, including contributing to the rise in antibiotic-resistant bacteria.

These so-called Lyme wars are one of the latest chapters in a long history of the medical establishment dismissing hard to define chronic illnesses – such as chronic fatigue syndrome or fibromyalgia – or chalking up symptoms to attention-seeking or misidentified mental health issues.

To find out more, Aucott and his colleagues are running studies that enrol people at the time of their skin rash, so it is clear they have recently contracted Lyme disease. These participants have also never been diagnosed with other chronic pain or fatigue conditions. "They get treated with standard antibiotic therapy and most people get better, but about 10 per cent don't," he says. "So I don't know how anyone could say it doesn't exist."

"There is no doubt that chronic Lyme exists. The question is the cause"



CDC/JAMES GATHANY

The "bullseye" rash doesn't appear on everyone infected with Lyme disease, and can be hard to spot on darker skin

He says there is now plenty of evidence to show that chronic Lyme, or what doctors now call post-treatment Lyme disease syndrome, definitely does exist. "[For people with Lyme disease], there's always a subgroup that has symptoms after therapy. There's really no doubt that they're there, the question is the cause. That's the controversy," says Aucott.

Because of the overlap in symptoms with some common pain and fatigue conditions, there aren't reliable figures for how many people report long-term Lyme symptoms. But some estimates suggest that up to 20 per cent of people who get Lyme disease may experience post-treatment symptoms. If that is the case, a recent analysis calculated that, in 2016, there would have been between 69,000 and 1.5 million people in the US with post-treatment Lyme disease. The estimates for 2020 reached as high as 1.9 million cases.

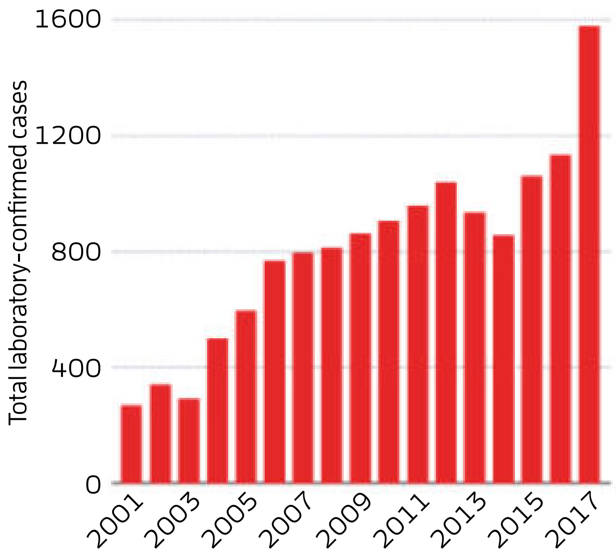
"That the numbers were so high was an eye-opener," says Alison DeLong at Brown University in Rhode Island, who worked on the study. She and her colleagues believe the increasing rates of post-treatment Lyme disease syndrome may not be restricted to the US, especially in light of climate change (see "Ticks in a warming world", page 44).

These people may be forever changed after a tick bite. "Normally if you have an

›

Lyme disease in the UK

Lyme disease is still considered uncommon by British health authorities, but the number of cases are steadily rising. As well as the reported cases in England and Wales (below), in most years since 2007, there have been more than 200 confirmed cases in Scotland



SOURCE: PUBLIC HEALTH ENGLAND; HEALTH PROTECTION SCOTLAND

acute infection, everything gets better in a few weeks. This illness, if you get this, you never feel good again. There's something profoundly altered in the physiology of this unfortunate subset [of people] that develops post-treatment Lyme disease syndrome," says Aucott.

There are several hypotheses as to what that could be. Aucott and his team have found that changes in the body's immune response brought on by altered gene regulation patterns are seen in people who have had Lyme disease. This supports the idea that the infection triggers an autoimmune response, in which the body turns against its own healthy cells. This wouldn't require the presence of living bacteria, which would explain the experience of ongoing fatigue and pain after antibiotic treatment.

Another possibility is that antibiotics don't kill all the bacteria and instead leave behind some damaged organisms. In animal studies, these zombie bacteria grow slowly, cause more severe arthritis symptoms and resist standard antibiotic treatment. Here, though, there is some hope: last year, a study led by Ying Zhang at Johns Hopkins University found that a cocktail of three antibiotics cleared these persistent bacteria from mice.

There is a third possibility that is a bit of both of these: the amber theory. "The bacteria are dead and killed, but may leave behind protein and cellular fragments as if preserved in amber," says Aucott. These fragments may cause inflammation that results in joint pain and stiffness. "But it's a little hard for me to imagine these not being cleared away by the body's immune system for years," he says.

It could also be that there are no bacteria left at all, but that the illness alters neural networks, rewiring how a person perceives pain and fatigue. The repetition of pain over several months or years may change a person's attention to, or even anticipation of, pain, creating a kind of feedback loop. "It's a neural pathway realignment that becomes self-perpetuating. And you see that in people with fibromyalgia," says Aucott.

Or it may be simpler than any of that. Post-treatment Lyme disease syndrome could be an entirely different condition caused by another bacteria passed on by ticks, says Campos. Just last year, a new tick-borne illness was identified in Mongolia after a farmer with a history of tick bites went to her local hospital complaining of fever and headaches. She tested negative for known tick-borne diseases, but when researchers analysed her blood and that of 86 others in the region with similar symptoms, they identified a new condition, naming it Alongshan virus after her hometown.

"We know ticks carry many bacteria and co-infection is quite common," says Campos. "But if you don't know what you're looking for, how do you test for it?"

Efforts are under way to create more reliable diagnostic tests, but for now, the best defence is to avoid tick bites (see "Tick check", page 42). Soon, though, we may have a vaccine for Lyme disease. There was one, Lymerix, on the market briefly in the late 1990s, but it was caught up in anti-vaccine sentiment on the rise at the time. Despite a US Food and Drug Administration study confirming it was safe, Lymerix was voluntarily pulled by the manufacturer, wary of an endless string of lawsuits.

A new vaccine on the way should be effective against the six types of *Borrelia* that cause most Lyme disease in the US and Europe. "We are developing these vaccines for people living in the northern hemisphere on both sides of the Atlantic," says Thomas Lingelbach, president of the French biotech company Valneva, which is running human trials of the vaccine. Depending on the type of bacteria, between 70 and 90 per cent of people in the trials develop antibodies, he says. The vaccine should be available in 2023.

The trick won't just be making sure that the vaccine works, though. It is also fighting anti-vaccine sentiment and building enough trust to get people to take it, says Lingelbach.

Knowing a vaccine is on the near horizon may help ease the worry of those living in areas where Lyme disease is rife. But it won't help people who already have chronic Lyme.

Acknowledging the reality of post-treatment Lyme disease syndrome is a crucial first step towards solving the mystery of what causes it, and developing treatments. But there is a long way to go before we can offer these people the relief that they seek. ▮

Ticks in a warming world

A warming climate makes new habitats suitable for ticks and can extend their lives – and, consequently, their chances of passing along pathogens. But it isn't just temperature that can affect the risk of contracting Lyme disease.

Sen Li at Huazhong University of Science and Technology in China and his colleagues modelled the risk of people catching Lyme disease in Europe under three future greenhouse gas emission scenarios.

They found that the high emissions scenario included enough deforestation that it may actually limit the places ticks live. The lowest risk of Lyme disease in these future models is in a scenario in which the world will warm by about 1.5°C by 2100.

Chelsea Whyte is a news editor at *New Scientist*. Follow her @chelswhyte

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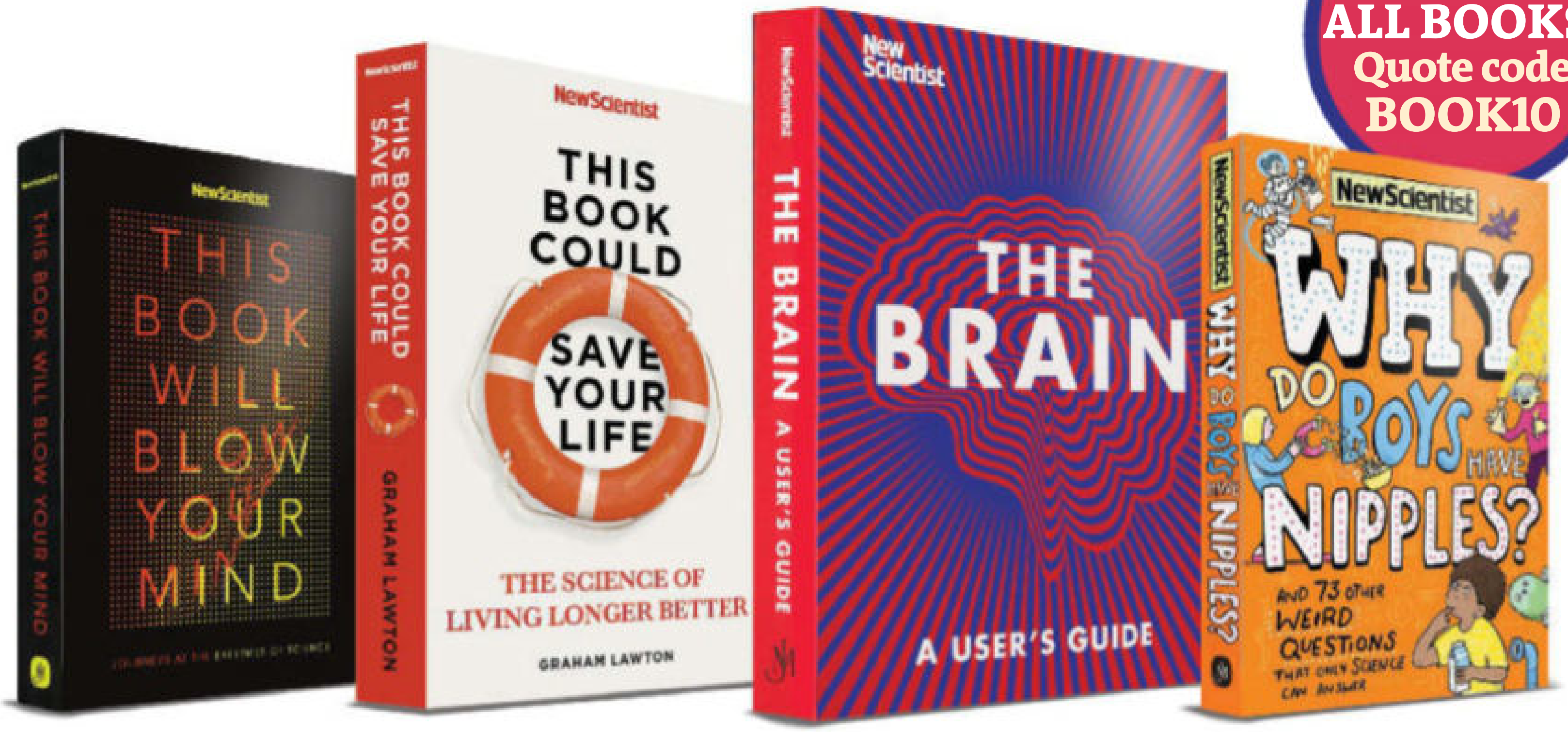

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What is reality? You can approach this question from many angles – by attempting to divine mathematical regularities and physical laws to describe what is "out there", for example, or by examining the relationship between any such objective reality and our subjective perception of it.

Implicit in most of these discussions is that idea that reality is somehow a "natural" construct, with set laws we can uncover. In this classic *New Scientist* article, reproduced in our new *Essential Guide: The Nature of Reality*, philosopher Nick Bostrom advances a very different idea – reality is made by people rather like us.

SCIENCE has revealed much about the world and our position within it. Generally, the findings have been humbling. The Earth isn't the centre of the universe. Our species descended from brutes. We are made of the same stuff as mud. We are moved by neurophysiological signals and subject to a variety of biological, psychological and sociological influences over which we have limited control and little understanding.

One of our remaining sources of pride is technological progress. Like the polyps that over time create coral reefs, the many generations of humans that have come before us have built up a vast technological infrastructure. Our habitat is now largely one of human making. The fact of technological progress is also in a sense humbling. It suggests that the most advanced technology we have today is extremely limited and primitive compared with what our descendants will have.

If we extrapolate these expected technological advances, and think through some of their logical implications, we arrive at another humbling conclusion: the "simulation argument", which has caused some stir since I published it in 2003.

The formal version of the argument requires some probability theory, but the underlying idea can be grasped without mathematics. It starts with the assumption that future civilisations will have enough computing power and programming skills to be able to create what I call "ancestor simulations". These would be detailed simulations of the simulators' predecessors – detailed enough for the simulated minds to be conscious and have the same kinds of experiences we have. Think of an ancestor simulation as a very realistic virtual reality environment, but one where the brains inhabiting the world are themselves part of the simulation.

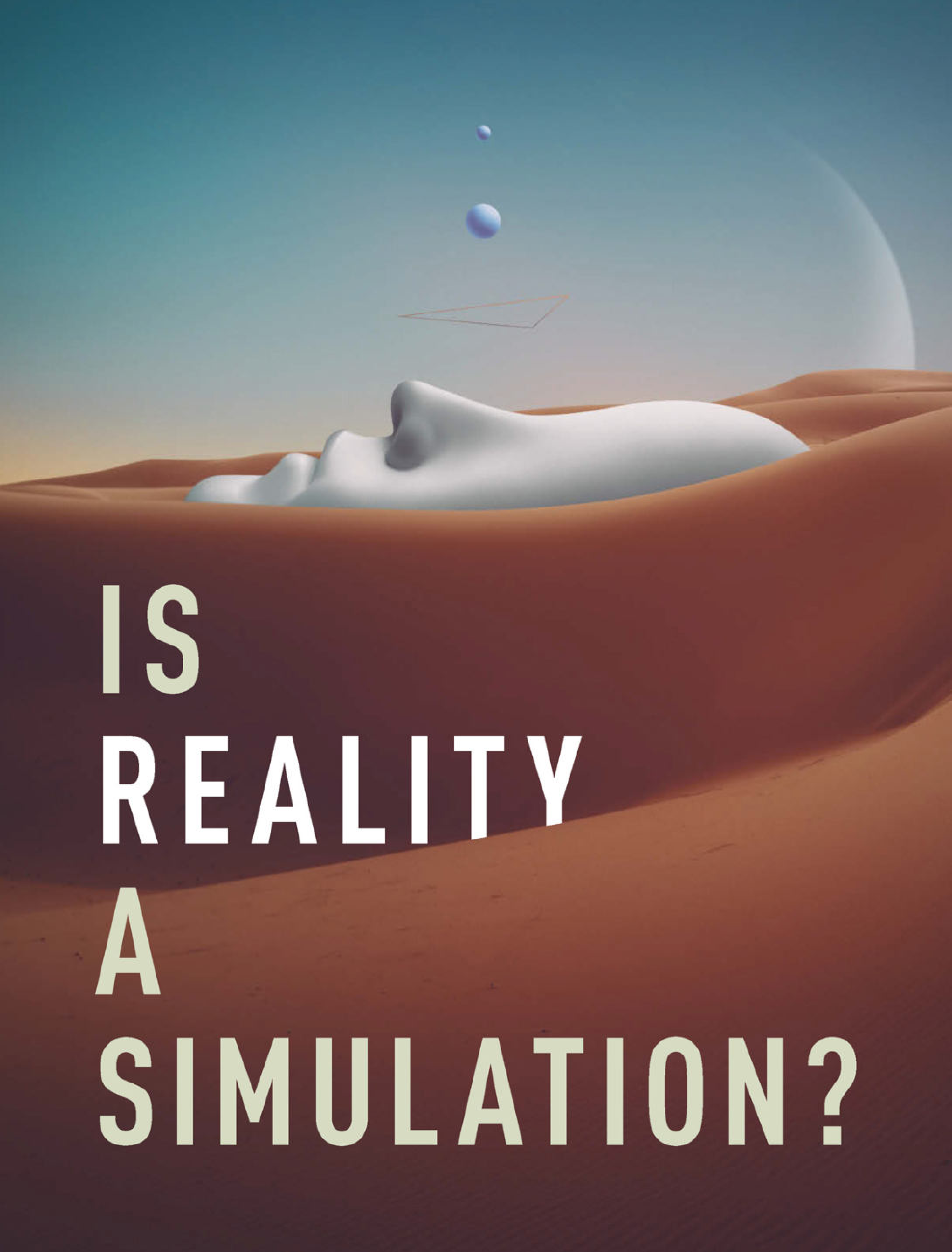
The simulation argument makes no assumption about how long it will take to develop this capacity. Some futurologists think it will happen within the next 50 years. But even if it takes 10 million years, it makes no difference to the argument.

Let me state what the conclusion of the argument is. It is that at least one of the following three propositions must be true:

- → **Almost all civilisations at our level of development become extinct before becoming technologically mature.**
- → **The fraction of technologically mature civilisations that are interested in creating ancestor simulations is almost zero.**
- → **You are almost certainly living in a computer simulation.**

How do we reach this conclusion? Suppose first that the first proposition is false. Then a significant ›

ANXO VIZCAÍNO



IS REALITY A SIMULATION?

"If we work out the numbers, we find there are vastly many more simulated minds"

fraction of civilisations at our level of development eventually become technologically mature. Suppose, too, that the second proposition is false. Then a significant fraction of these civilisations run ancestor simulations. Therefore, if both one and two are false, there will be simulated minds like ours.

If we work out the numbers, we find that there would be vastly many more simulated minds than non-simulated minds. We assume that technologically mature civilisations would have access to enormous amounts of computing power.

So enormous, in fact, that by devoting even a tiny fraction to ancestor simulations, they would be able to implement billions of simulations, each containing as many people as have ever existed. In other words, almost all minds like yours would be simulated. Therefore, by a very weak principle of indifference, you would have to assume that you are probably one of these simulated minds rather than one of the ones that aren't simulated.

Hence, if you think that propositions one and two are both false, you should accept the third. It is not coherent to reject all three.

It should be emphasised that the simulation argument does not show that you are living in a simulation. The conclusion is simply that at least one of the three propositions is true. It does not tell us which.

In reality, we don't have much specific information to tell us which of the three propositions might be true. In this situation, it might be reasonable to distribute our credence roughly evenly between them.

Let us consider the options in a little more detail. Proposition one is straightforward. For example, maybe there is some technology that every advanced civilisation eventually develops and which then destroys them. Let us hope this is not the case.

Proposition two requires that there is a strong convergence among all advanced civilisations, such that almost none of them are interested in running ancestor simulations. One can imagine various reasons that may lead civilisations to make this choice. Yet for proposition two to be true, virtually all civilisations would have to refrain. If this were true, it would be an interesting constraint on the future evolution of intelligent life.

The third possibility is philosophically the most intriguing. If it is correct, you are almost certainly living in a computer simulation that was created by some advanced civilisation. What Copernicus and Darwin and latter-day scientists have been discovering are the laws and workings of the simulated reality.

These laws might or might not be identical to those operating at the more fundamental level of reality where the computer that is running our simulation exists (which, of course, may itself be a simulation). In a way, our place in the world would be even humbler than we thought.

What kind of implications would this have? How should it change the way you live your life?

Your first reaction might be to think that if three is true, then all bets are off and you would go crazy. To reason thus would be an error. Even if we are in a simulation, the best methods of predicting what will happen next are still the familiar ones – extrapolation of past trends, scientific modelling and common sense. To a first approximation, if you thought you were in a simulation, you should get on with your life in much the same way as if you were convinced that you were leading a non-simulated life at the "bottom" level of reality.

If we are in a simulation, could we ever know for certain? If the simulators don't want us to find out, we probably never will. But if they choose to reveal themselves, they could do so. Another event that would let us conclude with a high degree of confidence that we are in a simulation is if we ever reach a point when we are about to switch on our own ancestor simulations. That would be very strong evidence against the first two propositions, leaving us only with the third. Welcome to reality. ▮

NICK BOSTROM is a philosopher and founder of the Future of Humanity Institute at the University of Oxford, and author of the book *Superintelligence: Paths, dangers, strategies*. This classic article originally appeared in *New Scientist* in 2006

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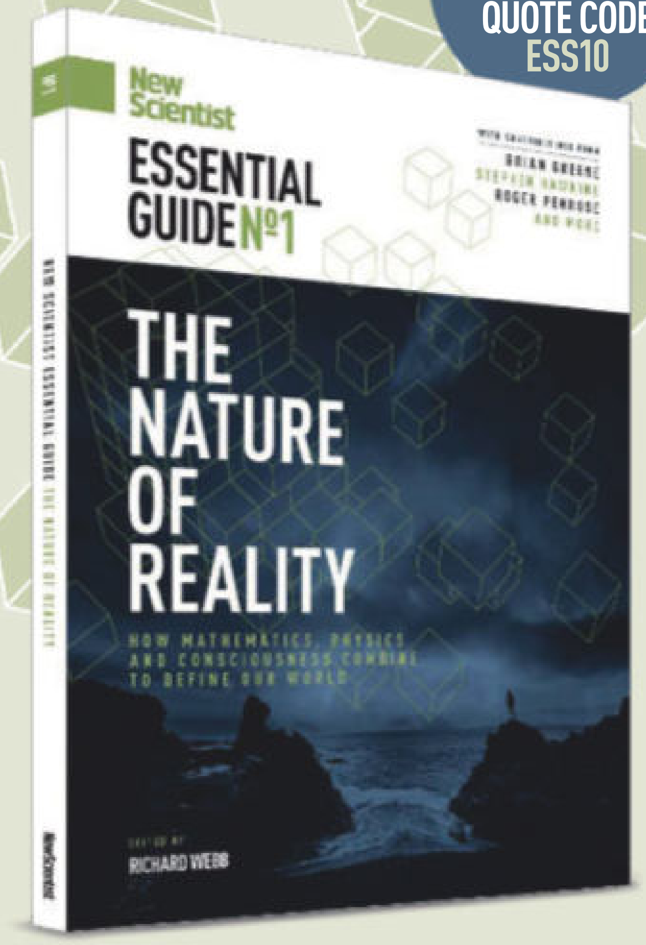

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HOW TO MEASURE THE SPEED OF LIGHT USING A CHOCOLATE BAR AND A MICROWAVE

This is an amazing experiment that actually allows you to measure one of the fundamentals of science – the speed of light – in your own home!

WHAT DO I NEED?

- a bar of chocolate (the longer the better)
- a ruler
- a microwave oven

WHAT DO I DO?

Remove the turntable from your microwave oven – the bar of chocolate needs to be stationary. Put the chocolate in the microwave and cook at high power until it starts to melt in two or three spots – this usually takes about 40 seconds. You should stop after 60 seconds maximum, for safety.

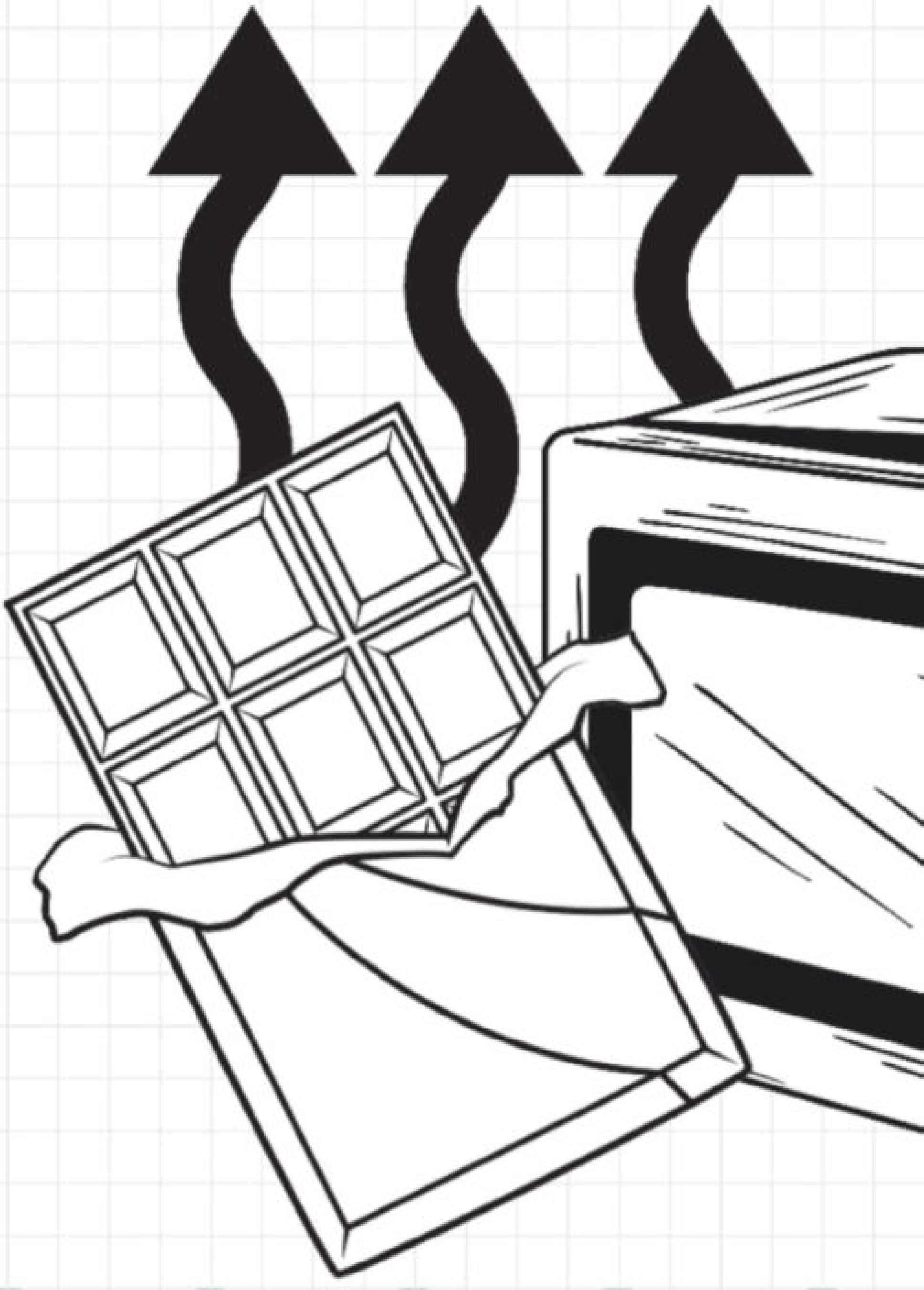
WHAT WILL I SEE?

Because the chocolate is not rotating, the microwaves the oven produces are not evenly distributed throughout the bar and spots of chocolate will begin to melt in the high-intensity areas or 'hotspots'. Remove the bar from the microwave and measure the distance between globs of melted chocolate.

WHAT'S GOING ON?

Microwave ovens get their name from the waves they use to cook food with: a form of electromagnetic radiation (just like light) called – wait for it – microwaves. These race through the air at the speed of light in a wavelike fashion of peaks and troughs.

The number of waves per second, also known as the frequency, is the key here. A standard oven will probably have a frequency of 2.45 gigahertz (the figure should be given on the back of the oven or in the instruction manual). If your oven is 2.45 GHz, this means the microwaves oscillate 2,450,000,000 times a second (you can adjust this figure depending on your particular oven).



So now you know how frequently the waves go up and down, you just need to know the distance between the peaks of the waves, which is known as the wavelength. That will help you to calculate how fast they are travelling.

This is where the chocolate comes in. Because the wave will melt the chocolate when it goes through it on the upward part of the wave and the downward part, the distance between the globs of molten chocolate is half the wavelength of the microwaves in your oven. So double the measurement you have taken of the gap between the molten globs to find the microwave wavelength. In the *New Scientist* microwave oven, the distance between the globs of molten chocolate was 6 cm, so the wavelength in our 2.45 GHz oven is 12 cm.

To calculate the speed of light in centimetres per second you need to multiply this wavelength by the frequency of the microwaves. So you do 12 x 2,450,000,000 = 29,400,000,000, which is astoundingly near to the true speed of light of 29,979,245,800cm per second (or 299,792,458 m per second as it is usually expressed).

EASY_COMPANY/ARKADIVNA/ISTOCKPHOTO.COM

Try it yourself, measuring as accurately as possible to get a figure even nearer to the true speed. If your chocolate bar is chilled beforehand, the molten areas tend to be more distinct when they first appear. Of course, you may find that a variety of different chocolate bars, all of which taste delicious slightly melted, will aid your research. True scientists know that it is always important to double-check results.

WHY DO BOYS HAVE NIPPLES?

Made especially for young and curious minds, *Why Do Boys Have Nipples?* (published as *Where Do Astronauts Put Their Dirty Underwear?* in the US) is based on *New Scientist*'s ever-popular Last Word column, and features 73 other weird questions only science can answer, plus plenty more fun experiments to try at home, too

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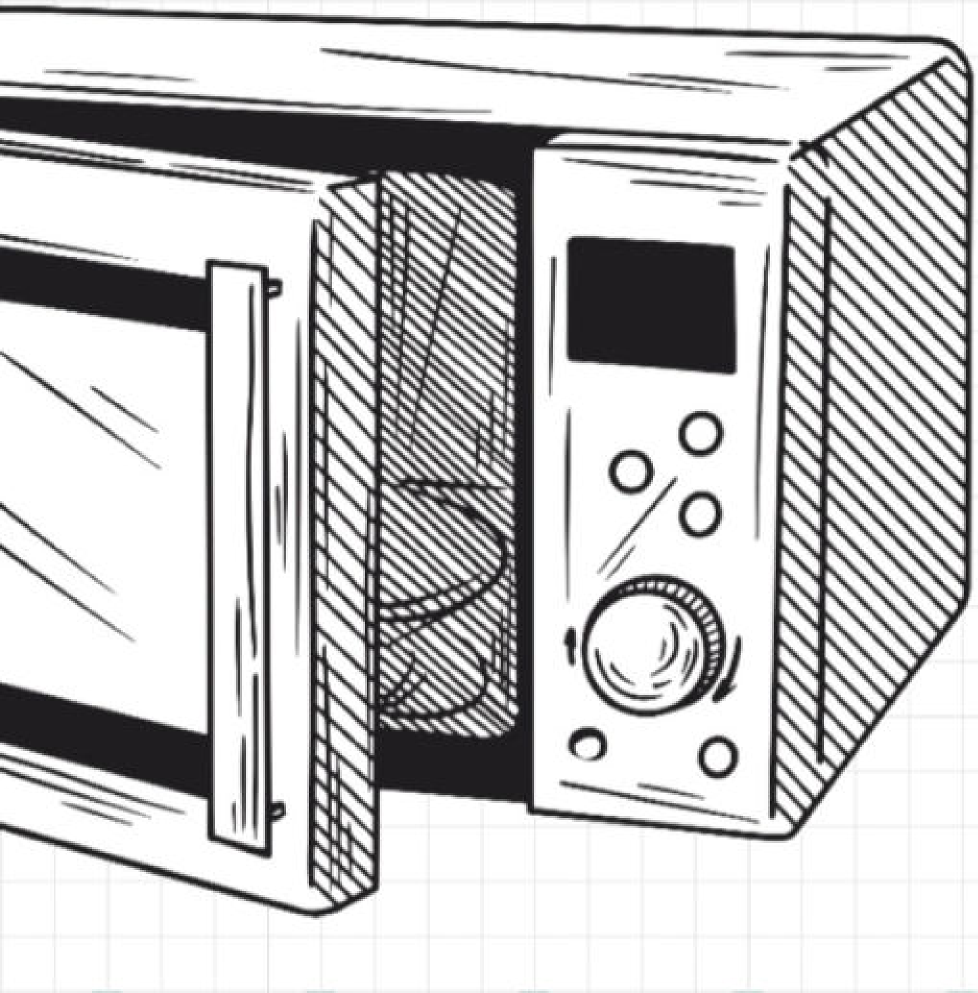

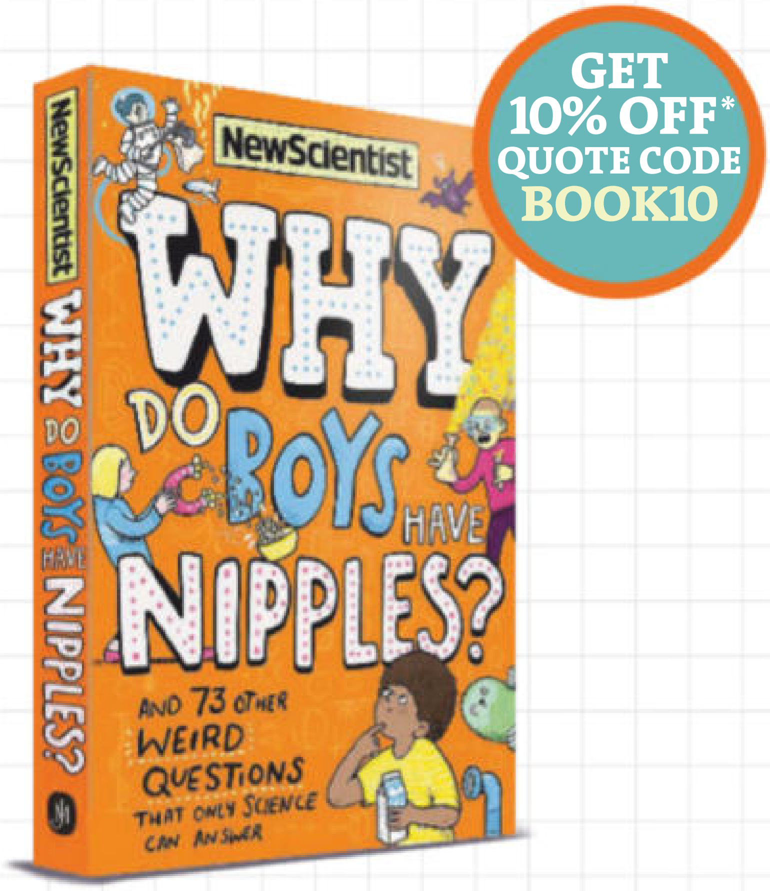
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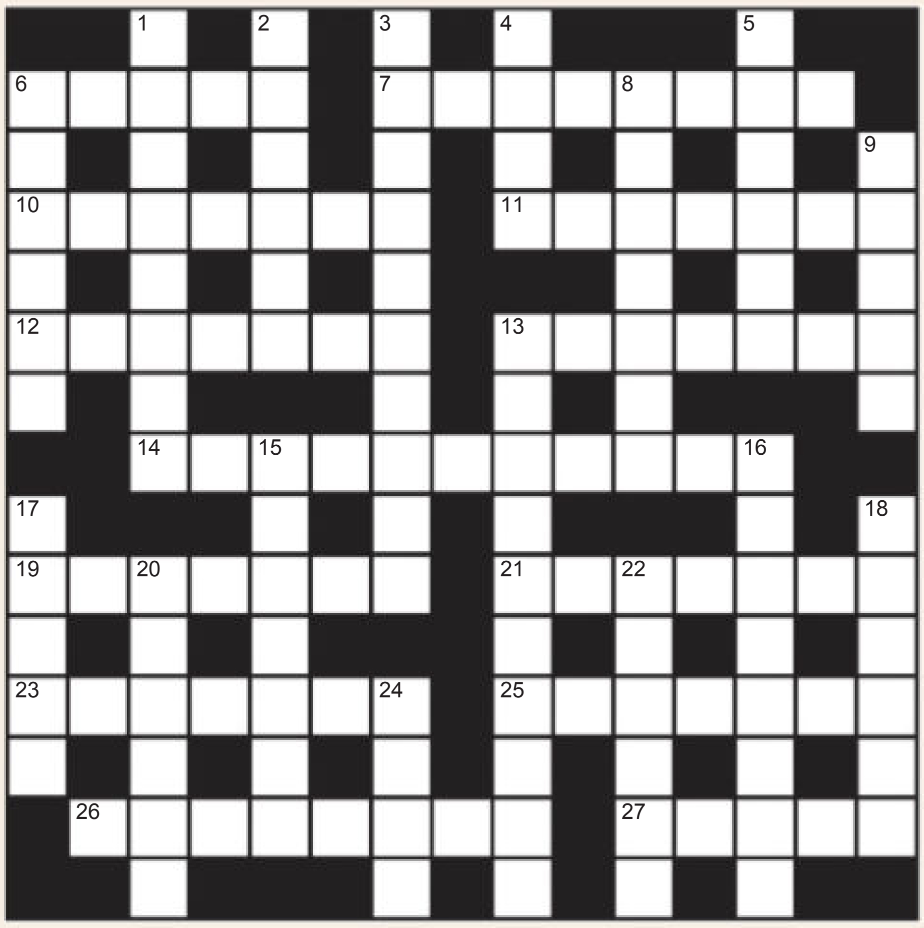
Puzzle
Can you work out the shortest routes, via a burger stop? p54

Cartoons
Life through the lens of Tom Gauld and Twisteddoodles p54

Feedback
Measuring distances with animals: The week in weird p55

Last word
Do bald men have an evolutionary edge? Readers respond p56

Quick crossword #59 *Set by Richard Smyth*



Scribble zone

Answers and the next cryptic crossword next week

ACROSS

6 Fulcrum (5)
7 Liverwort (8)
10 Era preceding the Triassic (7)
11 Pharma salesperson (4,3)
12 Vitellus (4,3)
13 Part of the throat (7)
14 The SeaTitan or Haliade-X, perhaps (4,7)
19 Rotating machine to multiply pulling force (7)
21 Cosmological origin theory (3,4)
23 Al_2O_3 (7)
25 Portable light-source (7)
26 Hinge joints (8)
27 Printed substrate; transfer (5)

DOWN

1 Exceed capacity (8)
2 ___ committee, body tasked with moral oversight of scientific research (6)
3 Painkiller, banned by the US FDA in 1983 (10)
4 Apple media player launched in 2001 (4)
5 Vitamin C deficiency (6)
6 Tropical fruit tree (6)
8 Wave series generated by water displacement, by, for example, an earthquake (7)
9 Cyclic ether with a three-atom ring, informally (5)
13 Quadric surface with one axis of symmetry and no centre of symmetry (10)
15 O (7)
16 Disappear (8)
17 Group of eight (5)
18 Of breathing: abnormal, laboured, irregular (6)
20 Connect to power supply (4,2)
22 Sex glands (6)
24 Radical derived from an aromatic hydrocarbon by the removal of one H atom (4)

Quick quiz #54

1 "Who ordered that?" This was physicist Isidor Isaac Rabi's response to the discovery of what particle in 1936?

2 Human babies are nidicolous. Why?

3 Bardeen, Brattain and Shockley are famous for what?

4 African-American chemist Alice Ball, who died in 1916 aged just 24, developed a successful treatment for which bacterial disease?

5 The epidemiological efforts of which doctor are recognised by a plaque on the side of an eponymous pub on Broadwick Street in Soho, London?

Answers on page 54

Cryptic Crossword #32
Answers

ACROSS **7** Entail, **8** Anoxia, **9** Read, **10** Milky Way, **11** Oedipus, **13** Saudi, **15** Horde, **17** Tachyon, **20** Spectrum, **21** Swig, **22** Astral, **23** Tattoo

DOWN **1** Annexe, **2** Band, **3** Olympus, **4** Yawls, **5** Polymath, **6** Ligand, **12** Inducers, **14** Mammoth, **16** Oppose, **18** Orison, **19** Prole, **21** Sett

Our crosswords are now solvable online
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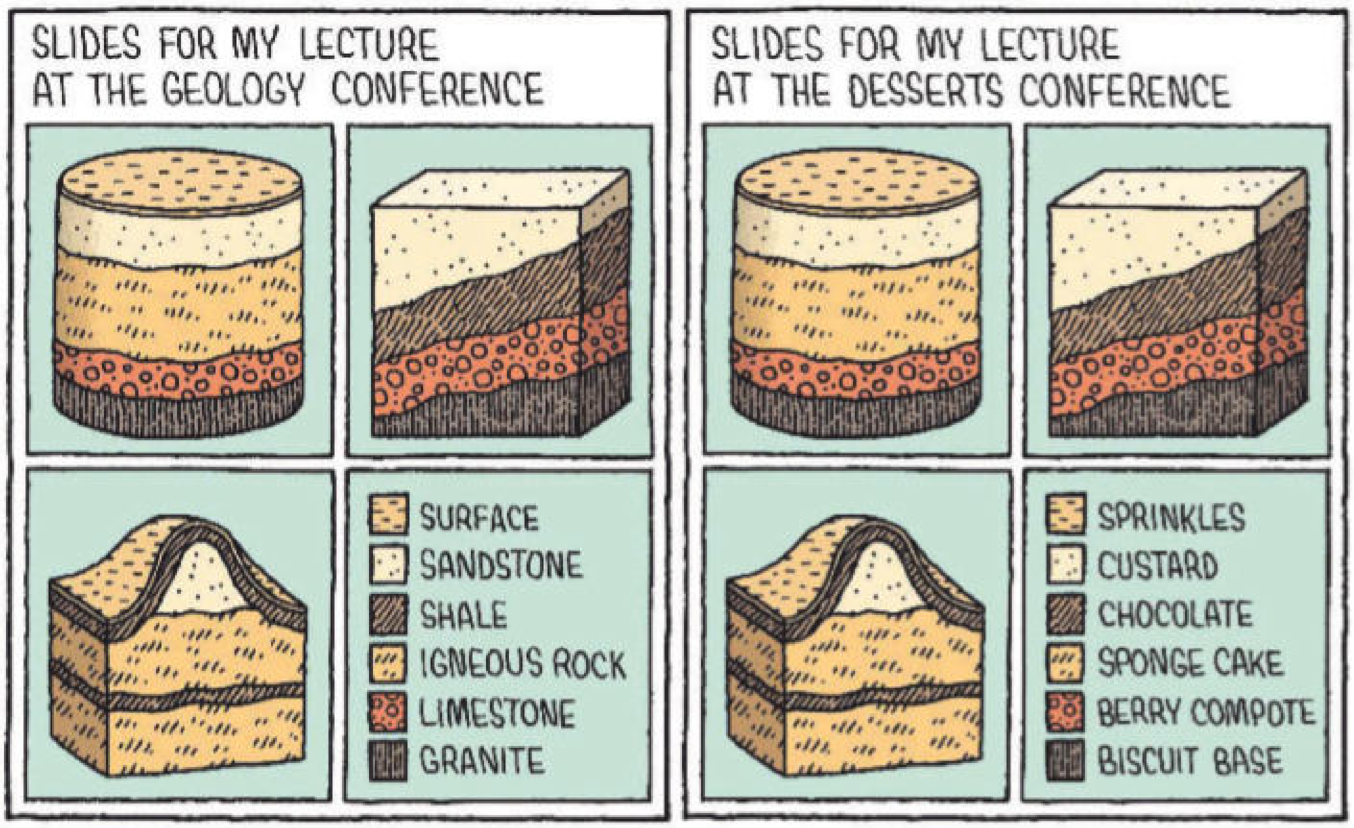
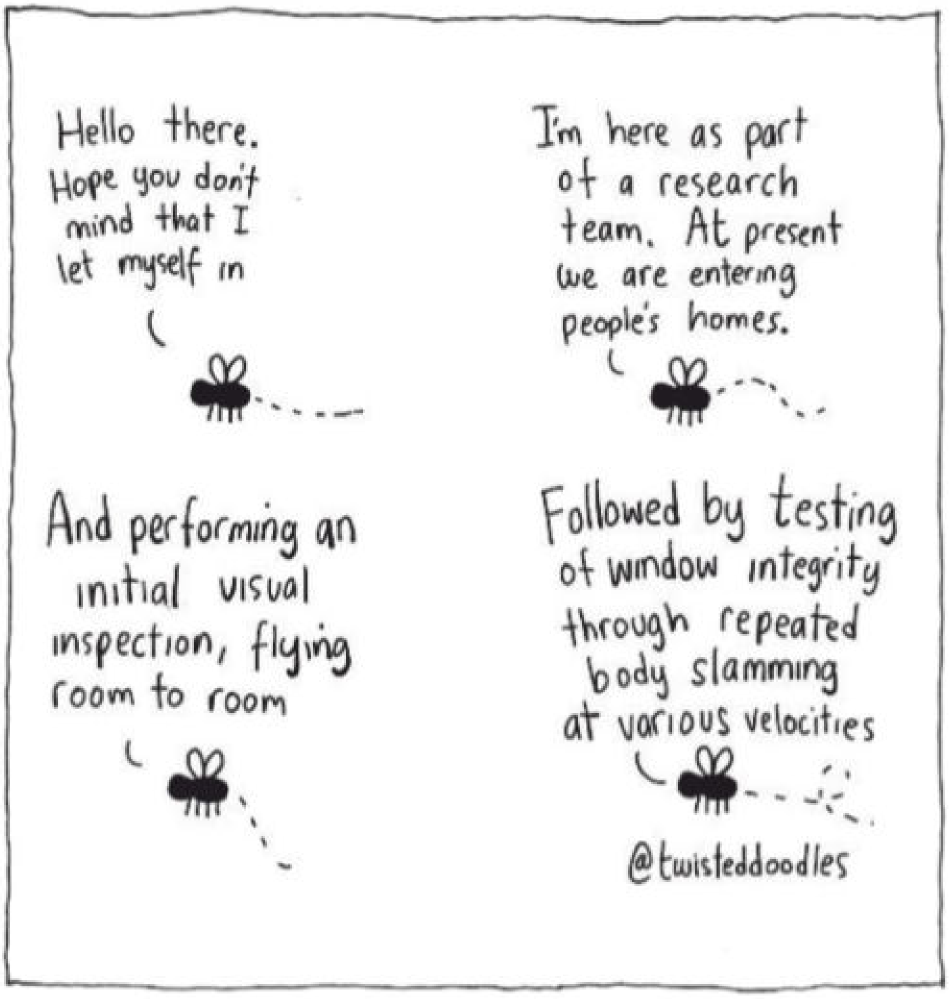
Tom Gauld

for New Scientist



Twisteddoodles

for New Scientist


Hello there. Hope you don't mind that I let myself in
I'm here as part of a research team. At present we are entering people's homes.
And performing an initial visual inspection, flying room to room
Followed by testing of window integrity through repeated body slamming at various velocities
@twisteddoodles

Quick quiz #54

Answers

1 The muon. A heavier version of the electron wasn't on anyone's menu

2 They are "nest-inhabiting", dependent on their parents for survival

3 The invention of the transistor in 1948, for which they received the Nobel prize in physics in 1956

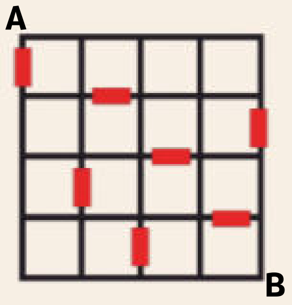
4 Leprosy; her story is told in a recent short film, *The Ball Method*

5 John Snow. He proved that the source of a cholera outbreak was the handle of a water pump just outside

Puzzle

set by David Bodycombe

#62 Burger run



Three friends agree to drive from A to B via the shortest road route possible (driving down or right at all times). They are hungry, so also want to drive through a Big Burger restaurant, marked in red. They are arguing about how many shortest routes will pass through exactly one Big Burger.

Xenia: "I reckon there are 10."

Yolanda: "I'd say more like 20."

Zara: "No you're both wrong, I bet there's more than 50."

Who is right, or closest to right?

Answer next week

61 Triple Jump

Solution

Let us call the mother's age when the triplets were born M, so she had her (M + 1)th birthday before the triplets' first birthday. The triplets' age is X. We are looking for a time when either M + X = 3X (i.e. M = 2X) or when M + X + 1 = 3X (i.e. M + 1 = 2X). So whether M is even or odd, there will always be a value of X that works.

If the triplets were born on the mother's Mth birthday, the ages will coincide when the mother is 1½M, which is only a whole number when M is even. In other words, if the triplets were born on the mother's birthday, the chance of an age match is just 50 per cent. Overall, ignoring leap years, the chance that mother and triplet ages will match is (364/365) + (½ x 1/365) = 729/730, so about 99.9 per cent.

Half a mile, crocodile

As lockdowns lift and restrictions begin to ease around the world, it remains more important than ever that we all continue to keep 2 metres apart. Fortunately for any northern hemispherites not blessed with an intuitive grasp of lengths, Feedback's Australian readers have been writing in with more examples of alternative units of measurement.

Will Kemp sends us photographic evidence of a sign promoting social distancing during post-seminar drinks at Charles Darwin University, which translates 1.5 metres into "108 Gouldian finches, 8 brush-tailed rabbit rats, 3 northern brushtail possums, 1 and a half barramundi, or one reasonably sized freshwater crocodile". The notice, he informs us, was designed by zoologist Cara Penton, and so we are prepared to take her calculations on trust.

Meanwhile, Betty Wood tells us: "When Litchfield National Park in the Northern Territory reopened a couple of weeks ago, people were urged to keep one kangaroo apart." Elsewhere in the Northern Territory, Andrew Shead says the distance translates to 10 footballs, six boomerangs or five sea turtles. All very sensible, of course, but Feedback's going to need a bigger backpack.

sad face

Shed a crying-face emoji or two for the fate of future WhatsApp conversations. As a result of the coronavirus pandemic, reports *The Guardian*, a new generation of emojis scheduled to be released in 2021 is likely to be delayed. That means making do with the same familiar faces for the foreseeable future – a task those of us in lockdown are all too used to.

When the Unicode Consortium does eventually get together to decide on new emojis to approve, Feedback hopes it reflects humanity's newly enlarged emotional vocabulary, expanding its range to include woman-who-cut-her-own-hair emoji, man-tired-of-cooking-the-same-dinners-12-weeks-in-a-row emoji, hand-sanitiser-chapped-fingers emoji and for-the-love-of-god-Kevin-put-yourself-on-mute emoji. Do send in your own suggestions to the usual address.

JOSIE FORD

Got a story for Feedback?

Send it to feedback@newscientist.com or
New Scientist, 25 Bedford Street, London WC2E 9ES
Consideration of items sent in the post will be delayed

Bloofish detherisms

This week's delightful bit of AI foolishness comes to you courtesy of software engineer Thomas Dimson. On his website "This word does not exist", you get to challenge a machine to invent definitions for entirely bloofish detherisms – which is to say, spartful-sounding collections of haplets that don't conglomn in the English whizooosh.

The AI behind the website also invents words of its own. Feedback's personal favourite, after hours of ill-spent time, is "Epipanemal – relating to the wallop or release of an animal", though "Kumaree – a pitcher-shaped indentation that deepens when the feet reach the ground" is also joyously odd.

Taking you out

Strange news from *The Times* this week, after, in its words: "A practical guide to critically appraising literature on health and social care has made a surprise appearance as one of the most popular books in Britain's libraries." A slight comic exaggeration, perhaps, as *Doing a Literature Review in Health and Social Care: A practical guide* by Helen Aveyard only made it into the top 20 in the West Midlands, but who are we to cast stones.

Among the few books that bested *Doing a Literature Review* in the charts were *The Midnight Line* by Lee Child and *NYPD Red* by James Patterson, both classic page-turners in the best airport bookshop tradition. All of which suggests that *Doing a Literature Review* is, in fact, an action-packed thriller…

Dr Jack Healthcare gazed through manfully narrowed eyes at the president of the exploitative scientific publishing firm. "Lower your paywall," he growled.

The other man sneeringly raised his handgun at Healthcare's face. "And why should I do that?" Healthcare narrowed his manful eyelids even further, until they were just narrow, manly slits in the rocky promontory of his face.

"Because I'm doing a literature review in health and social care," he grimaced, somehow. Then, with a swift movement of his left pinky toe, a gambit outlawed in seven countries and regarded as bad manners in 12 others, he sent his adversary flying through a window. As Healthcare watched him plummet to his doom, he widened his eyes again, grimaced again, and shrugged (for the first time). "Though maybe they should've picked someone else…"

Kim Possible

It is always disappointing to hear that your heroes have feet of clay. Unless, I suppose, your heroes are Pingu or Wallace and Gromit, or else Swiss artist Paul Klee, but even then that's more of a spoken joke and doesn't really work written down.

So Feedback empathises with the residents of North Korea, who have just been told that their leaders can't magically contract space at will. The Kim dynasty was long credited with the practice, referred to by South Korea's Yonhap News Agency as *chukjibeop*, in an attempt to boost their quasi-mythical status. Alas, a North Korean newspaper has apparently reported that: "In realistic terms, a person cannot suddenly disappear and reappear by folding space."

Written by Gilead Amit

Hair loss gain

Does male baldness convey any evolutionary advantage?

Stephen Adshead
Edinburgh, UK
Evolutionary traits tend to exist for two main reasons: survival and attracting a sexual partner.

Perhaps like a peacock's feathers, the hair on a man's head creates a visual display to attract members of the opposite sex, although this may have came to an abrupt end in the 1980s, thanks to the mullet hairstyle.

In any event, later in life, when survival supersedes producing offspring, the head sacrifices its hair and uses the energy saved elsewhere in the body. Perhaps men who are lucky enough to keep a full head of hair don't have their priorities right.

Martin Jenkins
London, UK
If the bald English stage and screen actor Cedric Hardwicke was right, the answer to this question is no. He observed that even if claims bald men are more sexually potent are right, they get fewer chances to prove it.

Also, a bald man would have been at a disadvantage in combat. A blow to the head may have its force softened by thick hair; a club to a bald head is more likely to fracture the skull.

In either case, the chances of a bald man contributing to the gene pool would have been reduced.

Donald Windsor
Norwich, New York, US
Male baldness may have had an evolutionary advantage that can readily be seen in a crowd of people of diverse ages, where bald heads stand out.

Once over the age of about 25, men tend toward baldness and their hairless heads would have been a clear sign of age-related seniority, which would have been an advantage in terms of survival.

Grey or white hair would have provided a similar function. My bald head is garnished with a ring of grey hair and my grey beard emphasises the wisdom befitting my advanced age of 86.

ART DIRECTORS & TRIP/ALAMY

Does the strength of magnets and magnetic ores decay over time?

This week's new questions

Fading force **My horseshoe magnet isn't as strong as it was. Does magnetism decay over time, like radioactivity?** ***Alan Moskwa,*** *Adelaide, South Australia*

Bird walk **Why do some birds bob their heads as they walk? Did any dinos do this?** ***Robert Entwistle,*** *Bracknell, Berkshire, UK*

Richard Gregson
Hereford, UK
When I was at medical school, I read a section about male pattern baldness in my dermatology book with great interest.

The male author noted that male pattern baldness seemed to convey no advantage and said that the idea that bald men made better lovers was an old wives' tale. I concluded that he, like me, was affected by this trait.

As far as I can tell, male pattern baldness conveys no evolutionary advantage. But a trait doesn't have to convey advantage for it to take hold in a population, it just needs to have no disadvantage.

An example of this is our inability to synthesise vitamin C. Our ancestors lost this ability when our diets became so high in vitamin C that there ceased to be any disadvantage in losing this capability.

In those circumstances, a mutation in the gene responsible for making vitamin C spread through the population. However, in more recent times when a shortage of food rich in vitamin C was sometimes a danger, this left us vulnerable to scurvy.

It is easy to set up a computer simulation to show how a trait with no advantage can take hold.

David Muir
Edinburgh, UK
Don't lament bald heads: they may confer an evolutionary advantage by protecting you from illnesses resulting from low levels of vitamin D.

Instead, think of bald heads as personal solar panels for the photosynthesis of vitamin D, the sunshine vitamin, which is vital to many aspects of health. Vitamin D is synthesised in the skin, but this process requires ultraviolet B rays (UVB) from sunlight, which is too weak to do this in northern latitudes during winter. As our prehistoric ancestors moved north, they lost their skin pigmentation to compensate for the diminishing UVB levels that they found at higher latitude. Baldness would have become an advantage due to the greater capacity to synthesise vitamin D in the skin of the bald pate.

Mike Follows
Sutton Coldfield,
West Midlands, UK
A 1996 study suggested male pattern baldness signals maturity and gravitas.

This may be a legacy from our past. Grooming that takes place among great apes can involve plucking hair – higher status apes receive more grooming and can exhibit alopecia.

What's more, in 2008, a study suggested that because it increases the area of skin exposed to sunlight, male pattern baldness may have evolved to increase the production of vitamin D.

This vitamin protects against prostate cancer, which interferes with reproduction and can lead to premature death.

But the onset of male pattern baldness tends to be after men reach fatherhood, so too late to remove bald men from the potential gene pool. This suggests it doesn't bestow any evolutionary advantage or disadvantage.

However, they may be seen as superior mates and better marriage material because they are perceived as more nurturing towards offspring and less likely to attract rival females.

Greying hair may have a similar association. For example, dominance in a gorilla troop is signalled with a silver patch of hair on the backs of older males. ▮

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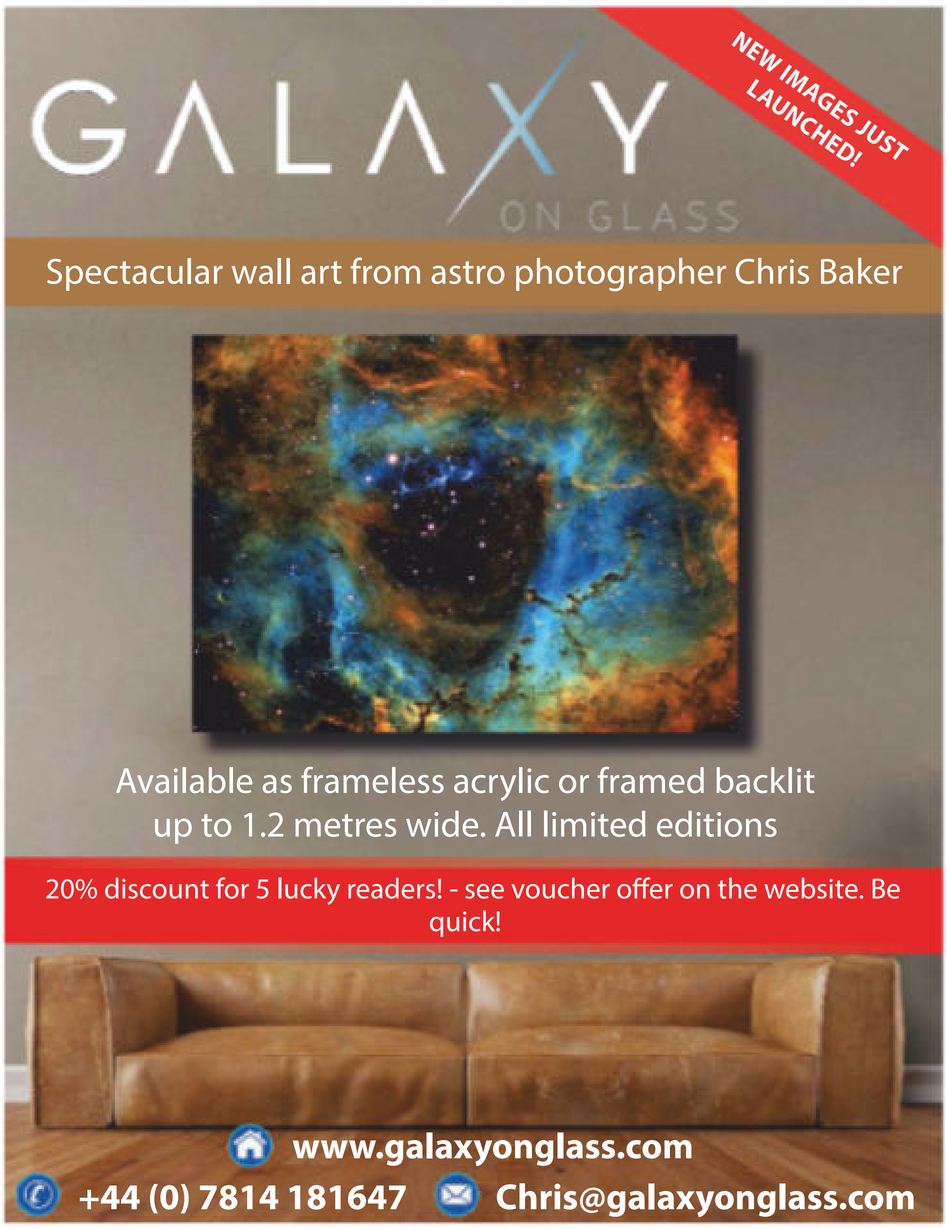

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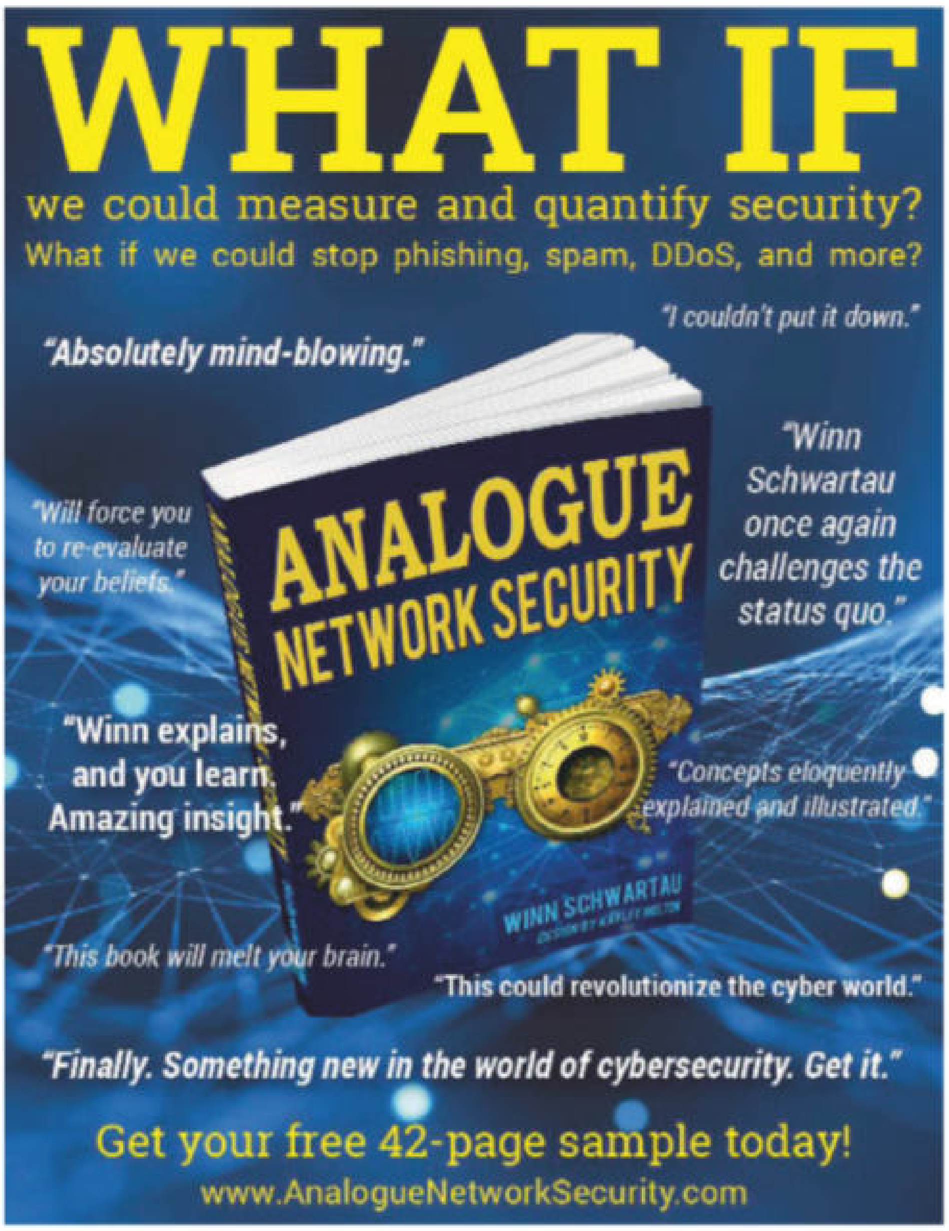

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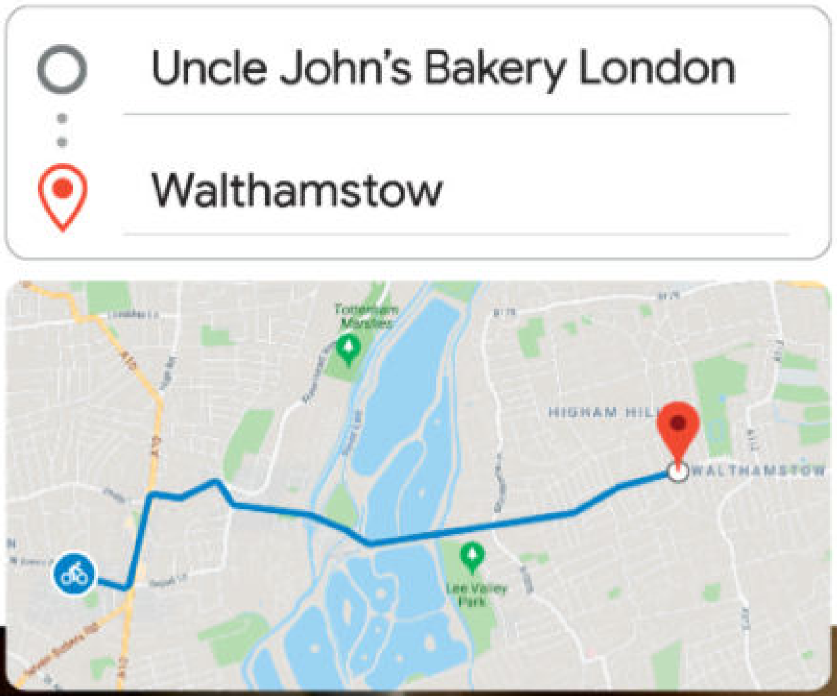
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